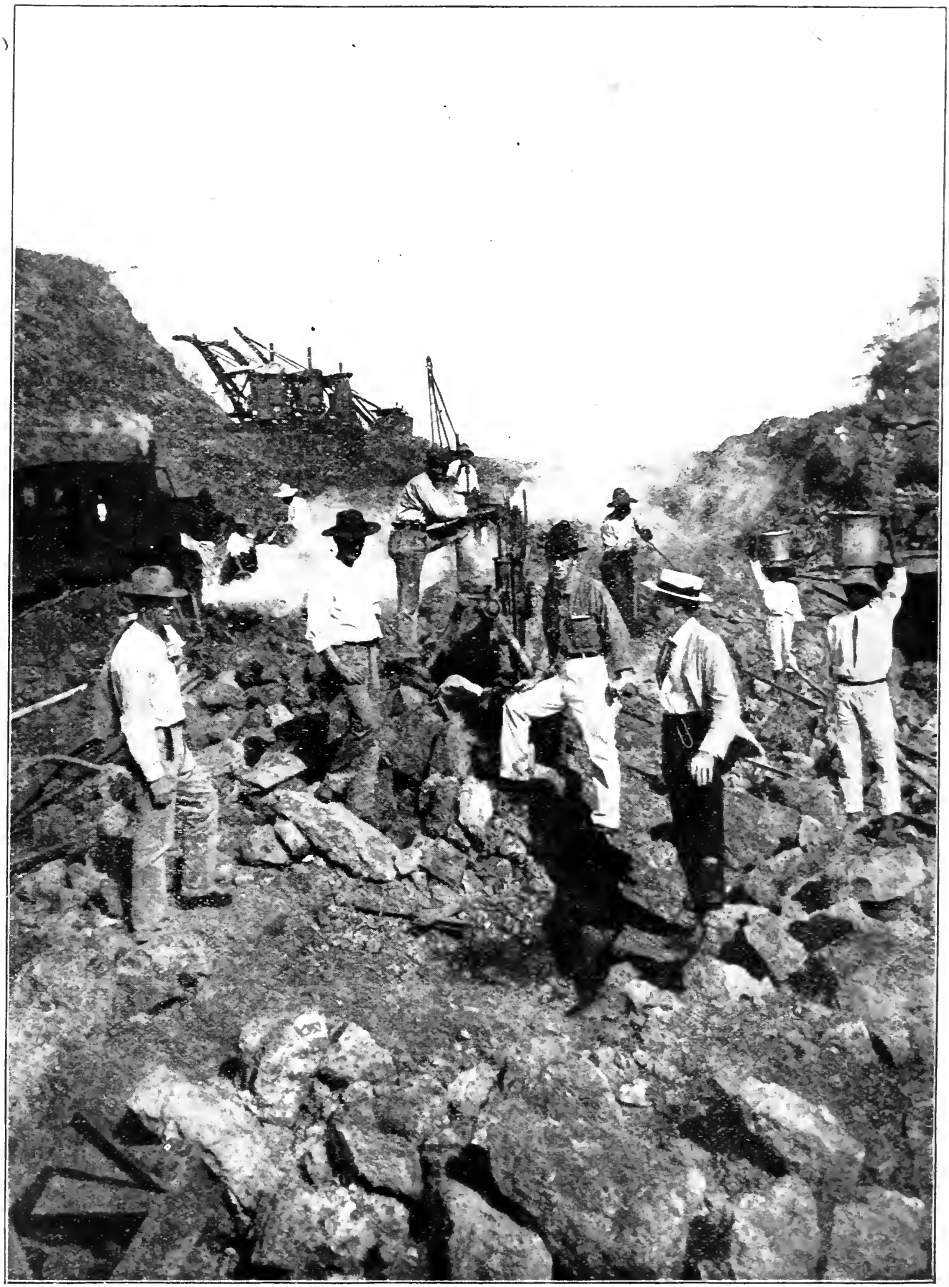
# COST ANALYSIS ENGINEERING

AMERICAN SCHOOL of CORRESPONDENCE
CHICAGO ILLINOIS



**BUILDING THE PANAMA CANAL**

Drill men at work in cut at Haut Obispo.

# COST-ANALYSIS ENGINEERING

INSTRUCTION PAPER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# COST-ANALYSIS ENGINEERING

**Definition.** Cost-Analysis Engineering is that branch of Engineering which has for its object the analysis of costs of construction or of operation, with a view to effecting a greater economy of production, and with a view to securing accuracy in estimating the probable cost of projected structures or operations.

**The Modern Manager a Cost-Analysis Engineer.** It takes few men to design machines and structures, but it takes many men to superintend their operation. Therefore the great field of activity for the engineer of the future is in the field of operation rather than of design.

Until very recent years, engineers have rested satisfied with being designers of labor-saving appliances. Now, however, they are beginning to assume the broader and more profitable function of operating the plants which their brains have created. To handle the ordinary industrial enterprise successfully, involves:

*First,* the application of engineering ability in selecting and improving the machines used;

*Second,* managerial ability in organizing the workmen, and in stimulating them to produce a large output economically;

*Third,* advertising ability to sell the product.

The man who combines in himself the maximum sum of these three abilities is the man best adapted to succeed as the executive of an industrial enterprise. Since the introduction of systems of cost analysis and unit-payments for work done, engineers have become best qualified to act as managers of manufacturing plants. We include contracting and railroading among manufacturing industries, for the contractor manufactures structures, and the railroader manufactures transportation.

Before cost analysis had been developed to its present stage of excellence, the successful manager of men was usually one who had relied upon his lynx eyes and his knowledge of the weaknesses of human nature. He was often a man who owed his success largely to the fear he could inspire in his subordinates. He was domineering; he held his men to their tasks; he was, indeed, an industrial captain;

and he used army discipline. He regarded every worker as a thief who would not hesitate at petty larceny of time, even in the face of the foreman, and who delighted in grand larceny behind his back. His foremen were his spies; and he set himself to spy upon his foremen. But cost-analysis engineering is evolving a wholly different class of managers and foremen.

To most people, a cost-keeping system means nothing but a sort of bookkeeping; and they are unable to understand how a bookkeeper can develop into a successful manager. But the truth is that modern cost keeping involves cost analysis, and cost analysis involves a study and comparison of methods and machines, and such a study leads to improvements and to commercial success.

Cost keeping, in the sense that we use the term, has for its main object the determination of the efficiency of men. A proper system of cost keeping tells you daily what each workman or each gang of workmen has accomplished. It is better than a foreman, for it cannot "stand in" with the men. It is better than a foreman, for it costs you less and it tells you more. A cost-keeping system tells you who are your good men, and who are your lazy men. It shows you whom to discharge, and whom to promote. It tells you whose wages are too high, and whose are not high enough. And, finally, it leads to that ideal condition of industrial organization known as *profit-sharing*. How often have we read in novels of Utopia, where all men share in the profits of all business; and how often have we smiled with incredulity at the prospect? Yet Utopia is right here in America, in spots; and it is a Utopia far more rational than that of the dreamers. There are many firms that pay their men on a unit-price or bonus system. This is profit-sharing, and it is a profit-sharing begotten by the use of cost-keeping systems; for, when a manager has learned by cost keeping that certain men or groups of men produce more than others, he soon perceives the advantage of stimulating them to further use of brain and muscle by paying them either a bonus for each unit produced in excess of a prescribed minimum, or a unit-price for each piece of work performed. The men invariably respond to this stimulus, and often in a remarkable degree. It is nothing unusual for a man to increase his output 50 per cent upon the introduction of a bonus system of payment; and there are many instances of increase amounting to 200 per cent. Each man then becomes a contractor,

and works with the zeal of a contractor, for his earnings increase as his energy and ability increase. This is practical profit-sharing that any workman can understand. It is not something vague and intangible, like 5 per cent per annum. It is something very real and immediate, for a man can feel it in the pay envelope at the end of every week.

Cost keeping, then, leads to better management, although dispensing largely with submanagers. It substitutes the record card for the "big stick," yet the record card itself is the biggest stick ever devised.

**The Science of Management.** The managing of industrial enterprises is still more or less of an art; but the art is fast passing through the period of evolution that produces a science. There are, unquestionably, certain underlying principles of management which can be summarized into rules or laws. These rules or laws constitute the science of management, and it is our purpose to present certain of the more important laws of management.

**Individual Incentive.** When a group of men undertake to do a certain piece of work, such as shoveling earth into a wagon, the tendency is for each man to do as little as his neighbor. The inevitable result is that the shovels move with rhythmic precision, and the slowest man becomes the pacemaker for the rest. If any one of the men is ambitious to do a larger day's work, he is deterred by the knowledge that his employer will never know that it is he to whom the credit is due for a larger output. Then, too, the other men are apt to upbraid an ambitious man, and urge him not to set a "bad example" by working fast. To offset this tendency to fall to the lowest level of efficiency, employers have placed foremen over their employees, the duty of these foremen being to accelerate the motions of the men in any way possible. Each foreman has an *individual incentive* to get work done economically, for his employer studies the total amount of work done by the gang under the foreman, and rewards or punishes the foreman accordingly, the reward usually consisting of praise and an increase in salary. But the workmen under such a foreman have no *individual incentive,* and they will shirk their tasks as far as possible. Clearly, then, the first law of management is to create an *individual incentive* for every employee to do his best.

**Creating Individual Incentive in a Gang.** There are, and always will be, certain kinds of work that must be performed by a group of men working together, or, as we shall call it, a *gang* of men.

When this is the case, the first step to be taken is to devise a method of readily and accurately measuring the work performed *each day*—not each week or each month—by the gang. The next step is to notify the men that, for all work performed daily in excess of a specified number of units of work, a bonus or premium will be paid for each excess unit. Of this bonus, the foreman will get a specified percentage, and the men will divide the rest among themselves. Thus a powerful individual incentive is created. It is true that certain men in the gang will remain less efficient than certain others, but the general average output will be greatly increased. The foreman himself will have enough incentive to see to it that the lazy or inefficient workmen in the gang are discharged, for it will no longer pay him to play the part of indulgence for the sake of being "a good fellow."

**Devising Ways of Dispensing with Gang Work.** Simply because it has always been the custom to do certain classes of work by gangs, should not deter a manager from endeavoring to devise a way of splitting the gang up into individual units. Indeed, it should be self-evident that if the creating of individual incentive is the fundamental law of management, a great amount of study may profitably be devoted to increasing individual incentive by doing away with gang work entirely. To illustrate, let us assume that 12 men are engaged in shoveling earth into wagons, working in two gangs of 6 men, with one foreman supervising the 12. If a sufficient number of teams and wagons are used, there will always be 2 wagons in the pit being loaded, and 6 men shoveling into each wagon. As fast as a wagon is loaded, it pulls out, and an empty one takes its place. If a manager is told that he can do away with this system of gang work, he will usually reply that it is impossible. Nevertheless, it is possible to reduce this gang work to individual work in most instances, as follows:

Instead of having 2 wagons and teams in the pit all the time, have 6 wagons without teams—6 empty wagons. Assign two men to each wagon. Provide a dividing board between the sides of each wagon, running either longitudinally or cross-wise, so that each man has his definite half of the wagon to fill. Then pair the men off according to their respective abilities, putting the two best men on one wagon, the two next best on another wagon, and so on. When a team brings an empty wagon into the pit, let it be unhooked from the empty wagon

and hooked to a loaded wagon, thus saving team time, which would otherwise be consumed in waiting for the wagon to be loaded.

It is possible to give many illustrations of this sort, but not desirable, for our object is to indicate the laws that should be applied, rather than to solve specific problems. The student of cost-analysis engineering will derive his greatest stimulus from applying the laws to specific cases that come under his own observations.

**Prompt Reward.** Most men believe in Heaven, and many believe in Hell; but few are greatly affected in their action by the hope of the one or the fear of the other. Any reward or punishment that is remote in the time of its application, has a relatively faint influence in determining the average man's conduct. To be most effective, the reward or punishment must follow swiftly upon the act. Hence a managerial policy that may be otherwise good is likely to fail if there is not a prompt reward for excellence. All profit-sharing systems have failed, principally because of failure to recognize the necessity of prompt reward, as well as because of failure to recognize the necessity of individual incentive. The lower the scale of intelligence, the more prompt should be the reward. A common laborer should receive at least a statement of what he has earned every day. If, in the morning, he receives a card stating that he earned $2.10 the previous day, he will go at his task with a vim, hoping to do better. But if he does not know what he has earned until the end of a week, his imagination is not apt to be vivid enough to spur him to do his best.

One contractor, known to the authors, has a large blackboard on which the hourly record of his brickmasons is chalked up. He has found that this constant record of where they stand in the day's race is a splendid stimulus.

**Sufficient Reward.** When a man produces more than has been his custom, he feels entitled to a very large percentage of his increased output. His sense of justice is keen on this matter, and rightly so. It is true that he is not entitled to all the increase, for his employer may have provided him with machines or tools of a better kind, for which payment must ultimately be made. Moreover, more rapid work with any machine means more rapid wearing-out of its parts, and a consequent expense to the employer. Finally, the employer who has used his brains to devise ways of increasing the output of the employees is entitled to a very substantial reward. No one begrudges Thomas

Edison his wealth. He has earned it by virtue of his inventions. In like manner, every man should be richly rewarded for every labor-saving machine or method which he creates or which he applies. However, employers are prone to try to take too large a part of the profit effected by an introduction of a system of unit-payment for work done.

Mr. Fred W. Taylor says that a workman should receive 30 to 100 per cent increase in wages upon the introduction of a piece-rate or bonus system of payment. Mr. Halsey says that the workman should receive one-third of increased value of his product resulting from an application of the bonus or premium system of payment. But the fact is that the employer should share liberally with his men; and, in the long run, the competition of other employers who are bidding for the services of workmen will force wages up to a point where the workman secures all but a very moderate percentage of the value of his daily product.

**Educational Supervision.** As previously stated, the old type of foreman mingles the functions of a spy with the functions of a mule-driver. The higher we go in the scale of human intelligence, however, the more noticeable is the fact that *the supervisors are teachers of the men they supervise.* These supervisors, foremen, managers—call them what you may—have learned that it pays better to spend time in training their men than to spend time in tongue-thrashing. Only of late years has it been discovered that systematic training of the least intelligent of workmen pays equally as well as the training of the most intelligent. The manager who recognizes the necessity of educational supervision, undertakes, first, a careful time study of each class of work. Then he analyzes the results, and deduces methods of securing greater economy. Having evolved a method of procedure, he reduces it to writing, and furnishes his foremen with detailed written or printed instructions to be followed, or, where the workmen are intelligent enough, the instructions are given to them directly; otherwise it is the function of the foreman to instruct the workmen.

**Divorce of Planning from Performance.** We have just spoken of the education of the workmen by the manager; but, before such education is possible, the manager must educate himself. In brief, he must study the problem and plan its most economic solution. According to the old-style method of management, each foreman was

left largely to his own resources in planning methods, and, added to this duty, he had several other duties to perform, such as "pounding the men on the back" when lazy, seeing that materials were promptly supplied, employing and discharging men, looking after the condition of machines, etc. This multiplicity of duties can be properly performed, only by a foreman possessed of a multiplicity of talents. Since few foremen can comply with such a specification for brains, it follows that good foremen of the old style are rare indeed. The modern system of management consists in taking away from the foreman the function of planning the work, and in providing a department that does all the planning. This planning department should be under the supervision of the Cost-Analysis Engineer, for it is he and his assistants who, by unit-timing of work and by cost keeping, are best able to ascertain what methods should be applied to get the most economic results. Having planned a method, the Cost-Analysis Engineer delegates its pursuance to one or more foremen.

**Subdivision of Duties.** The previous rule of action comes under another, still more general in character—namely, the law of the *subdivision of duties.* Men are gifted with faculties and muscles that are extremely variable. One man will excel at running a rock drill, another at keeping time, another at surveying, and so on. It is clear, therefore, that the fewer the duties that any one man has to perform, the easier it is to find men who can perform the task well. But give a man many duties to perform, and he is almost certain to do poorly in at least one respect, if not in several. One foreman may have a great knack at "keeping an eye on" machinery, and in having few breakdowns and delays. Then it is the part of wisdom to burden him with no other duties, unless the magnitude of the work does not warrant dividing the duties among two or more men. Let him be the *machinery and tool foreman,* reporting directly to the Cost-Analysis Engineer, and subordinate to no other foreman.

Another foreman may have a special knack at teaching workmen how to use tools and machines. Let him have no other duty but to see that the men have the proper tools, get them promptly, and use them properly. Let him be the *gang foreman.*

According to the magnitude of the work, there may be different kinds of foremen, all coming in contact with the same men, perhaps, but each performing different functions.

**Limitations of Military Organization.** Most industrial organizations to-day resemble military organizations, with their generals and intermediate officers, down to sergeants, each man reporting to but one man higher in rank. There is little doubt that the present tendency in industrial organizations is to abandon the military system to a very large extent, and for the following reasons:

A soldier has certain duties to perform, few in number, and simple in kind. Hence the man directly in command can control the actions of his subordinates easily and effectively. Control, moreover, should come invariably from the same officer, to avoid any possibility of disastrous confusion, and *to insure the instant action of a body of men as one single mass.*

On the other hand, industrial operations do not possess the same simplicity, particularly where men are using machines; nor is there the necessity of action in mass. The military organization, therefore, should be modified to suit the conditions; and one of these modifications is the introduction of two or more foremen in charge of certain functions or duties of the same men or groups of men, as explained in the paragraph on *Subdivision of Duties.*

**Opposition to Change.** All men have a certain mental inertia which makes them resist any change of their methods and habits. Foremen are particularly resistant to change, because of their custom of giving orders more frequently than receiving orders. Hence the Cost-Analysis Engineer who is trying to introduce modern methods is sure to meet with violent opposition from foremen; and the older the foreman, the more violent the opposition. When the Cost-Analysis Engineer introduces a new method, he must personally attend to every detail, or it will surely "go wrong." The old foreman will see to it that it does "go wrong," just to show that the "new-fangled ideas" are worthless.

Opposition may also develop among labor unions, particularly if it is proposed to pay on the piece-rate plan—that is, to pay so and so much for each unit of work performed. The bonus plan and the premium plan (to be described later) are schemes to overcome this opposition to the piece-rate plan, but in essence they are all the same.

No manager of men can attain great success unless he has grit enough and tact enough to overcome the opposition to change which he will encounter from all quarters. If he realizes in advance that

such opposition is as certain to manifest itself as it is certain that it takes power to change the direction or speed of motion of a heavy body, he will have possessed himself of one of the laws of successful management.

A man cannot impart motion to a very heavy rock by violent impact of his own body against it; but he can separate it into fragments, and move each fragment by itself. In like manner, no attempt should be made to change all the methods of an industrial organization at one stroke. Separate it into elements, and take one element at a time, beginning with the simplest. Apply your cost-keeping system to that element—it may be only the hauling of materials with teams—and effect the change desired. Then take another element of the organization, and apply the system to it. Continue thus, fragment by fragment, and you will overcome the opposition that would otherwise resist your greatest effort.

**Respect Your Own Ability.** One of the most common mistakes made by managers lies in assuming that a skilled workman necessarily knows better how to perform work than does the manager himself. A manager should first aim to familiarize himself with the methods used by the best workmen, and then, by an itemized time study, he should set his own wits to work to improve the methods. Workmen, for the most part, do their work just as robins build their nests—by the pattern of precedent. They put little or no brains into improving the process, because it usually means no money in their pockets to effect an improvement, and because they reason that an improvement that effects a saving in time may actually result in the discharge of some of their fellow workmen. It should be a cardinal law of management to give very little weight to the claims that workmen make as to their own skill or knowledge; and the same holds true as to foremen. Because a man has blasted rock for twenty years, should not make his opinion of such force as to prevent a manager from undertaking to show that man how to do rock-blasting more economically. We have frequently effected great economies in rock-blasting after a time study occupying fewer weeks than the blaster had occupied of years in the same sort of work. The trained mind of the Cost-Analysis Engineer enables him to analyze costs and methods, and to develop improvements which no amount of so-called "practical experience" can effect.

Weigh carefully every *reason* against any proposed change in

method, and act accordingly; but pay no attention whatsoever to predictions of failure that are bare of reasons. Do not be influenced even by many positive statements that your proposed method has been tried and has failed; for its failure may have been purposely brought about, or some small condition essential to its success may have been absent.

Therefore, respect your own ability. The manager who cannot improve upon methods used by his men is not fit to manage.

**Profit Does Not Mean Excellence.** Many a manager points to the profits of his business as the profit of his ability. He forgets that to a plainsman a small hill looks like a mountain. The general level of mediocrity makes such managers fancy that they are quite extraordinary if their business shows a large profit.

The Cost-Analysis Engineer can frequently take a profitable business and convert it into a wealth-producer beyond all dreams of the ordinary self-satisfied manager. Nor should the Cost-Analysis Engineer himself grow satisfied. *There is positively no limit to the economies in production which may be effected by the human brain.*

**The Human Engine.** The human body is an engine, or rather a boiler and engine combined. Its fuel is about 3 pounds of solid food daily, containing about as much energy as one pound of carbon or coal. One pound of coal will develop energy enough to perform about 10,000,000 foot-pounds of work; that is, it will raise 10,000,000 pounds one foot high, if there is no loss of power. But in all boilers and engines there is a loss of power, due to heat lost by radiation, heat carried away in the escaping gases and solids, etc., and heat developed by friction. A steam boiler and engine suffers so much loss of heat energy from these sources, that it rarely develops an efficiency of more than 10 per cent of the theoretical energy of the coal consumed. Curiously enough, the human body is not much more efficient than a steam boiler and engine; so that, while the one pound of carbon fed into the human body has a theoretical energy of about 10,000,000 foot-pounds, the actual useful work performed by a man is seldom more than 1,500,000 foot-pounds a day, or about 15 per cent of the theoretical energy of the food consumed.

When a man is walking, his whole body rises and falls each step, the rise being about one-seventh of a foot. Hence, in walking 25 miles in a day, about 2,000 steps per mile, a man weighing 140 pounds does 1,000,000 foot-pounds of work in raising the weight of his own body,

to say nothing of the energy consumed in swinging his legs. A man may walk the 25 miles in 10 hours, or he may walk it in 8 hours. In either case, he does substantially the same amount of work, and burns up substantially the same amount of food.

It should be clear, therefore, that when workmen are doing intermittent work, with periods of comparative rest, they are capable of working correspondingly harder during the periods of exertion. Thus, in running a rock drill, the physical labor is light, except when shifting the drill or when changing drill bits. At such times, the men should be required to work with great vigor in order to reduce the lost time.

It should also be clear that workmen should be taught to make no unnecessary movements of the body in doing work. Yet it is a fact that few workmen economize their energy by avoiding unnecessary motions.

It should also be clear that it pays to house workmen at no great distance from their work, so as to reduce the labor of going to and from the work; for every foot-pound of energy spent in going or coming reduces by that much the available energy of the man.

If it were practicable to measure the amount of resistance involved in doing each class of physical work, we could readily reduce to a science the setting of reasonable daily tasks. The authors are of the opinion that a careful study of *resistances* will eventually enable managers to fix certain tasks with great accuracy. To illustrate, let us assume that it is desired to know how much sand a workman should be able to shovel into a wagon box 5 feet from the ground in a day. It is not impracticable to measure the force required to push the shovel into the sand, and the distance pushed. The average weight of the earth on a shovel, and the weight of the shovel can be ascertained. The vertical height that this load is lifted, is easily measured. If the workman bends his body to fill the shovel, the weight of his body above the waist, multiplied by the height that the center of gravity of that weight travels will give the foot-pounds of work done in bending the body. And thus, by a calculation of each element of work done, an accurate forecast of the total possible work could be made.

Such a study as this will often disclose an unsuspected lack of economy in using certain tools. From such a study, for example, it is perfectly clear that the long-handled shovel, universally used in the far West for shoveling sand, gravel, etc., is a more economical tool than

the short-handled shovel used in the East. Men have argued about this matter for years without coming to a definite conclusion, the reason being that workmen accustomed to the short-handled shovel prefer it, while workmen accustomed to the long-handled shovel show an equal preference for that type of tool.

## COST GETTING

In taking of time and in the application of the cost of labor to the cost of work, there are probably as many systems as there are organizations doing work; and even within any one organization using a well-defined system throughout its entire operations, there will be no two men making the same interpretation of the rules laid down, or —more especially—whose methods of attack will be the same. But in spite of these many variations of method, there are several primary systems which are standard, and which can be found in one form or another on all properly conducted work.

The starting point of all cost getting is the taking of the time in the field, and it is here that the greatest variation in individual method is found. The most common way of taking this time record from which the pay-roll and the cost distribution is made, is for the time-keeper to go over the work with a notebook and put down therein with a pencil the number of each man and the particular part of the work that he is engaged on.

Two systems of record keeping, of which small cards form the basis, are also in vogue. One of these systems uses what is known as *punch-cards*—that is, cards in which the records of time, distribution, and performance are made by means of an ordinary conductor's punch; and the other has the record made in a way somewhat similar to the entries in a notebook—a written record being made on the cards with a pencil. Another system bases its records upon reports turned in by foremen.

**Time-Keeper with Notebook.** While the manner of taking time with a notebook varies according to the training and experience of the time-keeper, it may be said that there are in general two ways in which such notes are kept. In the first, the time-keeper has a list of the numbers of all men on the work, and, as he goes over the work, simply checks off the numbers, showing that each particular man is at work and indicating upon what branch of the work he is engaged.

A more common way, however, is for the time-keeper to make headings corresponding to the distribution used in making up the office records, and to write under each of these headings the numbers of the men working upon the part of the work so named. This method is often simplified by the time-keeper becoming so familiar with the foreman, and the numbers of the men under the particular foreman, that he is able to dispense with the headings entirely, and simply use the foreman's name or number in place of it. This, of course, makes the time-keeper's notes more or less unintelligible to anyone but himself, and makes it necessary for him to do office work as well as his field work. Moreover, not being a permanent or intelligible record, it is impossible for even the man who made the notes to return to them in case any dispute arises or a mistake is found to have been made, and get information after the notes have "grown cold." The time-keeper becomes so familiar with the appearance of the men who are on the work, that he learns to know their numbers, and often attempts to put them down without seeing their numbered checks. This is often a source of error, as the uneducated foreign laborer is very liable to make a mistake in stating his number; and if he does, there will exist no record of his having worked that day, and he will get no pay for it. The apportioning of the cost of his labor to any work that he may have been on, will also be the cause of trouble.

Of course, the time-keeper's memory serves him if any men are absent from the gang for any reason, and he is able to ask the foreman whether or not that particular man is working. A man may be away from the gang and be missed by the time-keeper altogether. In this case, no chance is given for correction of the record, unless the time-keeper goes over the work again soon after; and the consequence is that costs will be in error, and the men will be short of pay at the end of the month. This is especially liable to be true when night work is being done.

Men may be changed from gang to gang, or a whole gang may be changed from one job to another, and the time-keeper knows nothing of it unless he happens to be on the spot at just the right time. Such a change would not show in his time record; and while the men would get credit for their full time, the distribution of costs would be much in error. The difficulty in recording such changes can be seen from

the following extract from a report of a Consulting Engineer after inspecting work upon a road-making contract:

"In one case, at 10:30, there were eight men carrying stone to the crusher, and three men on the crusher platform. Two others were in the cut, loosening earth and loading; and half an hour later, two of the four men who had been blasting were also loosening and loading."

This, of course, indicates an unusually loose organization, but is an example of what a time-keeper with a notebook has to contend against.

Gang No.____ D & M. R. R. ____ ____ 1908
Foreman____ ____ ____ Track Laying

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Fig. 1. Time-Keeper's Slip.
Duplicate record is made automatically on a similar slip by carbon paper.

In case of emergency—say in steam shovel work—a train of dump cars goes over the side of a dump, and a track gang is called upon to help the regular dump gang so that the difficulty may be overcome as soon as possible. The time-keeper might fail to make record of an hour or an hour and a-half which the track gang put on this work, because he did not see them at work at that particular time. This, of course, affects the distribution of cost. One advantage from the notebook is that much of the distribution is made in the field, with a corresponding reduction of office work.

**Punch-Cards.** The keeping of time by means of punch-cards has been tried with considerable success on many jobs, but only recently

has it been reduced to a practical basis for use on large construction work.

The Construction Service Company of New York City has developed a system of time and cost keeping, using the duplicate punch-card almost entirely. Several of these cards are reproduced in connection with this text.

As a general thing, the punching of the cards is done by foremen of the gang, or by someone who has the performance of the gang under direct observation. The cards show not only the time worked by each man upon any one day, but just as exactly the time worked upon any job by all the men. A duplicate of the record is made automatically, to be kept in the time-keeper's office, the other going to headquarters for permanent record.

The record thus obtained is absolutely exact, especially as to distribution; but the system has some of the same objections that the notebook has. For instance, unless the cards are kept by the foreman himself, whoever punches them may inadvertently miss a man. This, however, is not so liable to happen as when a notebook is used. Whenever a single punch appears opposite a man's number, it is apparent that all his time must be accounted for in some way or other; while, with a notebook, it may be that, having been missed once, no record of any time will appear.

There is absolutely no opportunity for a time-keeper or for a foreman to "fudge" his account in any way, for a punch mark once made in the card cannot be erased or destroyed in any way. The record stands.

**Time-Keeper's Cards.** Instead of the time-keeper keeping his records in a notebook, as has been described, he may be provided with slips of tough paper of such size and shape as will readily go into his pocket, or will fit in a filing cabinet.

The *modus operandi* of these cards or slips is as follows:

Each card or slip is devoted to but one gang and one ledger account—such, for example, as placing ties in railroad work, gang No. 6. It will show the foreman's name; the name or number, or both, of each man; and the amount of time that he spent on this particular class of work. The sum of the amounts for the gang on this classification, will be the cost for this gang and this account for the day in question.

If a man has been working at more than one piece of work on that day, the time-keeper makes the apportionment of time on the spot; and the portion of his time that he has spent placing ties is put on the "Placing Ties" card or slip. The remainder of his time is placed on another slip corresponding to the other ledger account. If the time-keeper is uncertain as to which ledger account the work belongs to, he writes a description of the work at the top of the card or slip. A convenient form for a slip is illustrated in Fig. 1; and a convenient form for a file card, in Fig. 2.

It is frequently of advantage to have time-cards show, in addition to their pay and work performed, a log of the conditions, such as tem-

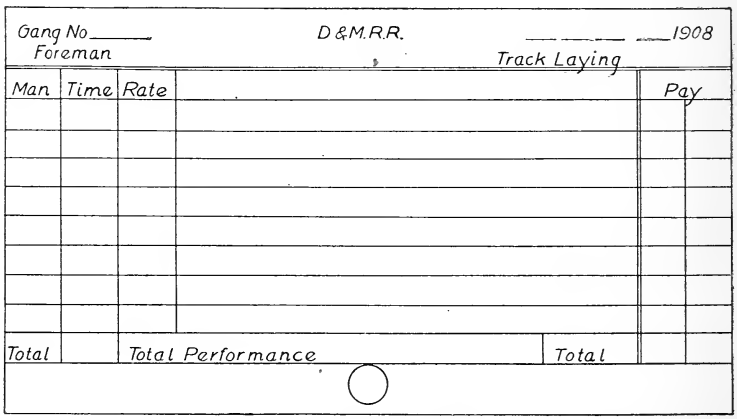



Fig. 2. Time-Keeper's Card.
Duplicate record is made automatically on similar card by carbon paper.

perature and weather; the causes and duration of each delay; the general conditions on the work; the kind, condition, and the make of tools, machinery, etc.; and any further details that may be important. How this can be done on the various cards illustrated in this volume, can be seen from a study of the illustrations.

**Written Time-Cards** have the advantage of the minimum of departure from existing methods; the disadvantages that arise are slight; and it is difficult to so arrange the cards as to obtain duplicates. A foreman with a dirty thumb will make a paper sheet on which he writes in the field look as if it had been dragged through the mud; while, with a punch, he can bring his card in with comparatively small damage. In general, it may be said that for the time-keeper's use the written

card has a slight advantage over the punch-card; while the reverse is the case for records to be obtained by the foreman, or whenever the men, such as drillers or teamsters, hold their own cards.

**Foreman's Report.** When the making-up of the pay-roll and the distribution of cost depend upon the reports of foremen, many serious difficulties are introduced into the work. Most foremen are intelligent enough to make a satisfactory report, and even more of them are honest enough to make a correct report. It is a curious fact, however, that among men of this class, while they would use every care in accounting for money entrusted to them, there is no tendency to consider time in the same light; and in consequence the reports of time given are liable to be very lax.

Moreover, if a foreman felt so inclined, if there were no one checking him or his reports, it would be a very simple matter for him to "fudge" his accounts so as to be able to acquire considerable graft.

If the foreman is intelligent and conscientious, a report and a distribution can be obtained from him which would be very easy to work into an excellent office record. Unfortunately, the desired combination seldom obtains, and there are very few large works carried on with such a system of time-keeping.

**Cost Distribution.** The time having been taken in the field, it now becomes necessary to make a distribution of costs in the office. The cost is that which is paid for producing work, being the material and labor cost of production, added to the proper proportions of expense cost, the expense being incurred in carrying on the operation and so making the actual work a possibility. The distribution of the cost is necessary in order that the contractor may see whether or not any particular operation is profitable; and a detailed analysis of the distribution, such as will be given later, will indicate in what respect the work may be made cheaper and more profitable.

In all cost distribution, there are certain items which cause trouble; and their proper disposition has led to much discussion among authorities on them, and has been the source of many different arrangements for their proper apportioning to the various operations on the work. For instance, there is the time of such men as are engaged upon water-supply service, drainage systems, the blacksmith, machinists, electricians, water boy, the time of watchmen, police, etc., which may come under the heading of "general labor;" and there are

such items as the transportation and distribution of coal to various parts of the work, the transportation and handling of stores, and numerous other items which, while seemingly affecting the whole work, are directly chargeable to some particular operation.

In many instances of distribution, the item of *General Expenses*, which includes the expense of store-keeper, time-keeper, bookkeepers, clerks, and such office force as may be required, is rather difficult of disposition. Those items which are usually monthly, may be distributed daily at a rate per day found by dividing the monthly rate by the number of days in the month, or they may be lumped at the end of the month and apportioned to the various operations. If they are distributed from day to day, it is rather difficult to tell just what proportion of them should go to each operation, as the cost of any operation is liable to vary greatly from day to day. If they are left to the end of the month, it is impossible to tell from day to day the exact cost of the work.

*Overhead Expenses* are another source of difficulty. Under this heading can be placed all salaries which do not ordinarily appear upon the pay-roll, such as the salary of the General Manager of the work, the Chief Engineer, and the officers of the company, and such expenses as office rent, telephone, office furniture, stationery, etc. Just where General Expenses leave off, and Overhead Expenses begin, is rather hard to determine, the line of demarcation varying in almost all cases.

One of the greatest troubles in distribution is caused by overtime of men who are on a daily and monthly basis. Under the same head might be placed *Lost Foreman's Time*—that is, the time which the monthly and daily men are paid for, and which produces no output.

## TIME-KEEPER'S NOTEBOOK

A page from a time-keeper's notebook is reproduced in Fig. 3. The necessity for an explanation of such a record is apparent. The work on which this record was made, was a job of rock excavation on which two steam shovels were being used, and the time and output of each shovel were kept separately. The record was made on the 17th of the month.

At the left of the page, within the curved line under the heading "*sh.* 2," we have the names of the shovel crew and the numbers of the pit men. At the side of these names and numbers, is the record of the

performance of the shovel of the day previous, the 16th, the shovel runner having given it to the time-keeper while the latter was on his first round on the 17th. Just below the record of the shovel, there are four numbers under a heading *Ditch*. In order to drain the shovel pit, it was necessary to use four men for cutting a ditch, and the time of these men is charged to the shovel. Underneath the record for the No. 2 shovel, is the record of shovel No. 1. It is recorded in exactly the same way as the other record.

In the center of the page, at the top, is the record of the drill gang for each shovel. There were six drills working in gang No. 2; but the record does not show this clearly, as there are two columns of six numbers each, one column being the driller's numbers, and the other being those of the drill helpers. Then there is a column of four numbers representing the muckers.

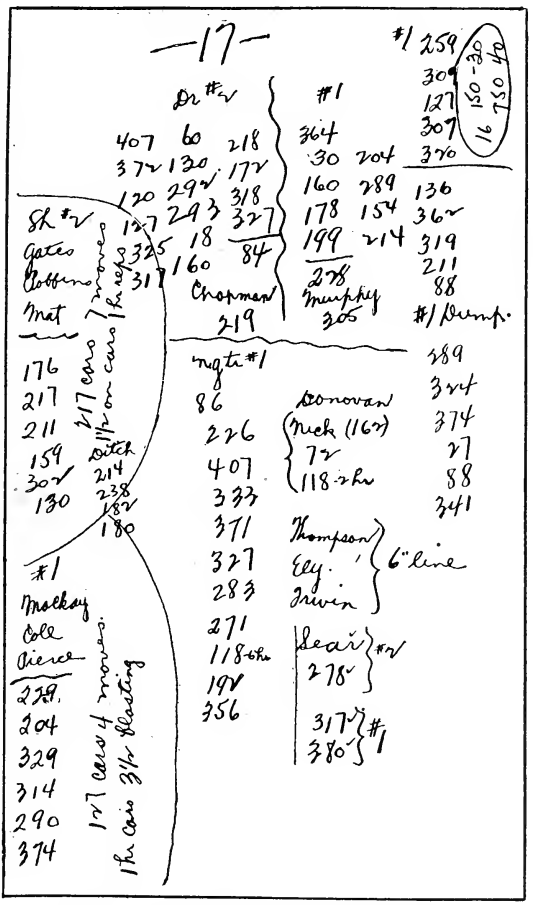



Fig. 3. Page from a Time-Keeper's Notebook.

The time-keeper knows, of course, which is which; but if for any reason anyone else than himself had to use the notes in the office, they would be useless. The number under the line is that of the man who carries bits to and from the blacksmith. The name of the fireman

of the boiler which furnishes steam to the drills is given, and the number of his helper.

The record of gang No. 1 is given in the same garbled manner, there being 5 drillers, 5 helpers, and 4 muckers in the gang, besides the man carrying bits, the fireman (whose name is given), and his helper. It will be noticed that in neither gang is the name or number of the foreman given, the time-keeper relying upon his memory to make the record complete in the office.

In the upper right-hand corner of the page, is the record of the blasting gang, in front of shovel No. 1. There are 5 men, including the foreman, whose number is given first. Within the ring is shown the number of pounds of powder used on the previous day as reported by the foreman. The record reads "on the 16th, 150 pounds of 30 % powder, and 750 pounds of 40 %."

Directly below this, midway down the page, is the record of the men working on dump No. 1. The foreman's number heads the list, the numbers of his men following.

Just to the right of the shovel records, and below the record for drill gang No. 2, is the heading "*ng. tr.* # 1;" and the men whose numbers are under this heading are engaged in laying and repairing the narrow-gauge track for the dump trains from shovel No. 1. Just below the middle of the page, is a list of names and numbers utterly unintelligible to anyone but the one who made it. The facts are these: *Donovan* is the man who looked after the storage of powder; within the bracket, *Nick* (the time-keeper, not knowing the last name, used his number, as well as the part of the name that he knows) is the blacksmith; and No. 72 is his helper; No. 118 helped the blacksmith for two hours, having been taken from the narrow-gauge track gang. The time-keeper had to depend entirely upon the blacksmith telling him this, or his record would have been incomplete. The next three men whose names appear in this column were engaged upon repairing a 6-inch pipe line; and the next two pairs within brackets, marked No. 2 and No. 1, are the pipe-fitters for the drill gangs and shovels No. 2 and No. 1 respectively.

### DISTRIBUTION FROM TIME-KEEPER'S NOTEBOOK

The time-keeper, having taken his notes over the entire job, sends them to the office so that the time may be posted for each man, and the distribution made.

The time-keeper goes over his notes, and picks out the items that are chargeable to drilling. In gang No. 2, there are 6 drillers at 30 cents per hour; 6 helpers, 4 muckers, 1 man carrying bits, and one fireman's helper, all at 17 cents, and one fireman at 25 cents. From the note at the bottom of the page, he knows (although no one else would) that *Lear* at 20 cents and No. 278 at 17 cents, were also with this gang. This, with the foreman at $3.50 per day, figures to $29.08. These are the charges that go directly to drilling, being the cost of time of the men actually engaged upon that operation and nothing else. But besides this, there must be apportioned to this cost a certain part of the Superintendent's salary, a portion of the labor on the 6-inch water pipe and the whole water system, a portion of the time of the blacksmith, the watchman, the storekeeper, the time-keeper, clerks, the water boy, and numerous other items.

In exactly the same way, the cost of the operation of the steam shovels is figured. For instance, No. 2 has an engineer at $125, a cranesman at $100, and a fireman at $75, a month, and 6 pitmen at 20 cents per hour, making the total charge of crew $19.27. To this the time-keeper added $5.44 as the cost of digging the ditch that drains the shovel pit. To charge this whole amount against the shovel for that day, is manifestly unjust, as the work of draining through this ditch will continue for many days, always facilitating the work of the shovel. The cost of subsequent days' work is lessened, while the cost of this particular day, as given with the $5.44 charge against it, is entirely too high. The spreading of an item of this kind is an extremely difficult matter, but it must be done. The steam-shovel cost must also have its proportional share of the charge for Superintendent, water system, blacksmith, etc.

The charge for narrow-gauge track is $14.86, being the time of one foreman at 20 cents, and 9 men for 8 hours and one man for 6 hours at 17 cents. The charge against No. 1 dump is $8.40, being the time for one foreman at 20 cents, and 5 men for 8 hours at 17 cents. The cost of blasting is figured exactly the same way, and the 900 pounds of powder used entered in the material account charged against the work in front of shovel No. 1.

The headings for the distribution of steam-shovel work, aside from *Drilling* and *Blasting*, would be *Shovel crew*, *Pit crew*, *Dump crew*, *Laying shovel track*, *Train crew*, and *Laying narrow-gauge track*, all

of which in the end can be summarized under *Loading and Transporting*, and the unit-cost of moving a yard of material figured from this summary.

## PUNCH-CARDS

The manner in which the time-keeper takes his notes in a note-book has been shown, and the impracticability of many of its phases pointed out. Two punch-cards for use on such work as that mentioned —namely, rock excavation with steam shovels and dump trains—are shown in Figs. 4 and 5. They are the *Steam-Shovel Card* and the *Train Record*. The shovel card is kept by the shovel runner or the fireman, and the train record is kept by the dinkey runner. Each keeps his own record separately; and, at the end of the day's work, the records must check each other.

The steam-shovel card shows the date, the number of cars loaded per hour, and the total number loaded per day. It also shows the time of starting and stopping the shovel for any reason, the stops for moving up being indicated in a different way from other stops; and thus a record of moves is kept automatically. The time of the shovel crew and the exact number of hours worked by the pit crew, are also shown, together with the cubic feet of coal consumed by the shovel. The causes of delays and the condition of the shovel are written in the blank spaces under their proper heading at the bottom of the card; but with this exception, the entire record is made with the use of an ordinary conductor's punch.

The train card shows the number of trips made by a train each day, the time of leaving the shovel on any trip being shown to the nearest 5 minutes. The number of cars hauled by all the trains during any hour must check with the number of cars loaded, as shown on the shovel card. The train card, besides showing the date, shows the total number of cars hauled (the total of all cards must check the total cars as shown by the steam-shovel record), the cubic feet of coal consumed, the average yardage per car, the haul in stations of 100 feet, the number of the dinkey engine, and a report of its condition, whether it be good, fair, or bad. This card is signed with the dinkey runner's name.

It will be seen that the record is very much more complete than that taken by the time-keeper, and is more reliable as to methods, being made while the work is going on; and the greater part of it is checked by having two records made separately, instead of taking a verbal

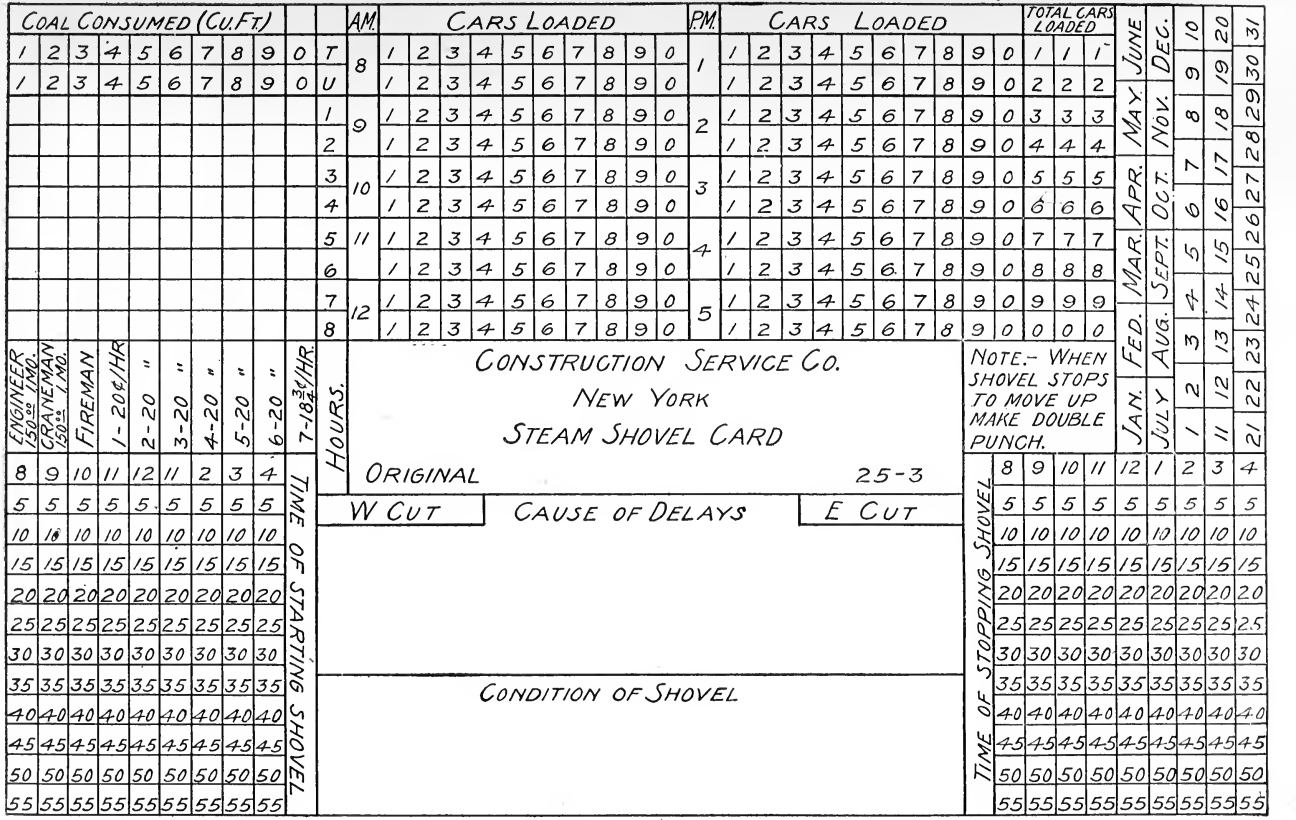



Fig. 4. Punch-Card for Recording Work of Excavation with Steam Shovel.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Hour | Time of Leaving Shovel - Minutes | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Number of Trip | | | | | | | | | | | | | | | | | 4 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 2 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 12 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 11 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 10 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 9 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| | | | | | | | | | | | | | | | | | | | | | | | | | 8 | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |

Punch each trip No. opposite time of leaving shovel.

Construction Service Co.
New York
Train Record
Original 2-08. 25-2A

| Condition | G | F | B |
|---|---|---|---|
| Eng. No. | 1 | 2 | 3 | 4 | 5 | 6 |

Haul in 100 Ft Stations

| Tens | ½ | 1 | 2 | 3 | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | U 3 | N 4 | I 5 | T 6 | S 7 | 8 | 9 |

Total No. Cars Hauled

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | H 2 | U 3 | N 4 | D 5 | R 6 | E 7 | D 8 | S 9 | 0 |
| 1 | 2 | 3 | T 4 | E 5 | N 6 | S 7 | 8 | 9 | 0 |
| 1 | 2 | U 3 | N 4 | I 5 | T 6 | S 7 | 8 | 9 | 0 |

Rate of Pay

Runner 75.00 per Mo.

Brakeman 18¾¢/Hr.

| Jan. | Feb. | Mar | Apr. |
|---|---|---|---|
| May | June | July | Aug. |
| Sept. | Oct. | Nov. | Dec. |

Cu. Ft. Coal Consumed

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | T 4 | E 5 | N 6 | S 7 | 8 | 9 | 0 |
| 1 | 2 | 3 | U 4 | N 5 | I 6 | T 7 | S 8 | 9 | 0 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |

Adverage Yardage per Car

| Tens | 1 | 2 | 3 | 4 | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | U 5 | N 6 | I 7 | T 8 | S 9 | 0 |

W | Cut | E | Runner's Name

Fig. 5. Punch-Card for Recording Work of Dump Trains in Excavation Work.

report from the shovel runner the following day as in the example previously shown.

Neither the train record nor shovel card, however, show any distribution of time, but are really performance records. The pipe and steamfitter's card reproduced in Fig. 6 gives an excellent example of how the time is taken and the distribution automatically made all at one time.

The classifications of labor are: Shovel, Channeler, Drills, Dinkey, and Trains, Pump, Tank, General Water System, and Blacksmith, being lettered, it will be noticed, from *A* to *H* at the head of the column. Each card provides space for the record of the foreman and 14 men. These eight classifications will probably cover all the work that the pipe and steamfitters are called upon to do; but if not, there are two extra lines on which can be written any classifications out of the ordinary.

There will be certain men assigned to certain regular work, as in the case previously quoted under the head of the Time-Keeper's Notebook, where there were two pipemen for each drill outfit. If these men spend their entire day of eight hours doing nothing but looking after the water supply for the drills, a punch mark would be made above the number of each of them on the card and opposite the figure 8, which represents the hours worked. To the left of the eight, and in the same line, and also in the vertical column opposite the word *Drills*, another punch mark will be made. Again, opposite the letter *C*, which is the key for the classification of drills, and in the column assigned to each man, and below his name, another punch mark will be made. This gives the workman full time, showing that he worked eight hours on drill water supply and nothing else. Suppose the foreman worked three hours on the general water system, three hours on the pumping station, and two hours directing the repair of the water tank. There would then be on the record a punch mark in his column opposite 3, 6, and 8; at the left of 3 in the column headed *G*, another punch will appear; at the left of 6 in the column *E*, another punch will be found, and still another at the left of 8 in the column *F*. In the column under the foreman's name, punch marks would be made opposite *E*, *F*, and *G*, showing that he worked on these three classifications.

In the same way, the time and occupation of each man under this foreman can be indicated, no matter how many changes he may make

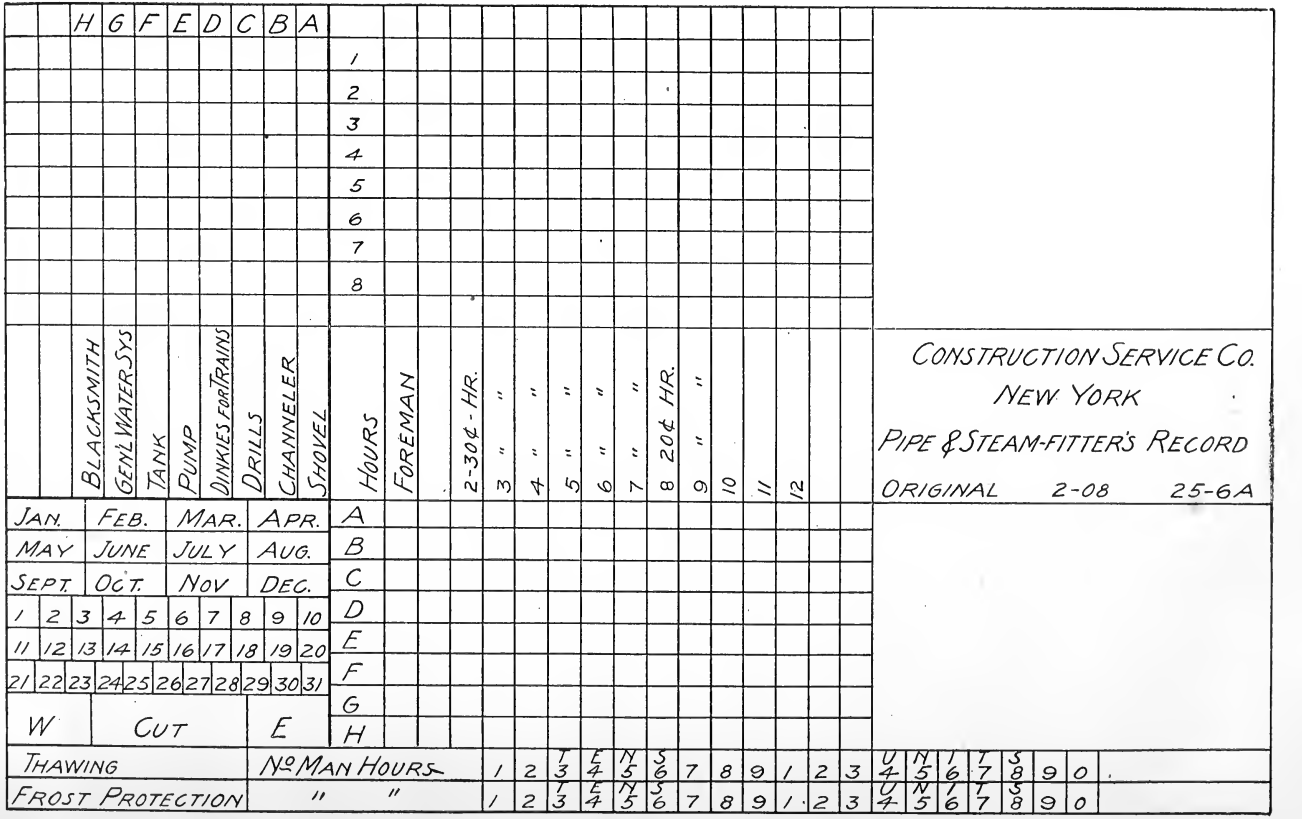



Fig. 6. Pipe and Steamfitter's Card, Showing Method of Taking Time, and of Simultaneous Automatic Distribution.

in his work during the day. The time, however, is recorded only to the nearest hour.

Provision is made in the lower left-hand corner, for the punching of the date; and along the lower edge is the place for the recording of the number of hours used in thawing the pipes, etc., and in providing protection for them. This latter record was found necessary, because the work on which these cards were used was done in an extremely cold locality and continued throughout the entire year.

When the records are made in the field and are sent in to the office to be transferred to permanent records, it is not necessary for the man who made the record to be at hand to interpret his notes, as there is absolutely no opportunity given him to allow his note taking to vary in the least from day to day, the record being absolutely automatic.

## PROCESS COST SUBDIVISION

While the object of the regular distribution of cost is the obtaining of unit-costs, there is another cost analysis which may be called a refinement of the cost-keeping system, and which, if properly used, can bring about a marked reduction in all costs. While this will be discussed more fully in the chapter upon *Reduction of Cost*, it is a form of time-keeping, and so will be touched upon here. On more or less rough construction work, it seems rather absurd to attempt to reduce the various processes of any operation to such a fineness that they may be timed to minutes and even to seconds. Conditions vary so greatly, the character of the work being done changes so much from time to time, and the personnel of the organization is sometimes shifted so much, that it seems impossible to reduce performance to any satisfactory basis which may be used as a standard. Nevertheless, without attempting to reach such a basis, careful watching and timing of the different parts of the work will result in much better performance and increased profits, as can be clearly shown.

Take, for instance, a driller working with a steam drill in fairly even rock, with no marked obstacles in his way and with very little mucking to do. Notice the exact time at which his tripod is in place and the drill ready to work. The driller places his bit in the drill, turns on the steam, and the drill starts. Note the time of starting the drill; note the time when the drill stops, the bit having gone down its full length; and do the same with each subsequent bit, noting care-

fully the exact time consumed in changing. When the last bit is down its full length and the hole is finished, note the time required to take out the bit, move the weights, loosen the tripod, and make everything ready for the moving. Then note just how many men are required to move the drill, and just how long it takes them to do it; and finally, how long it takes the driller to get his drill again in working order and started.

It will be found that a large majority of drillers take entirely too much time in the changing of bits, and that almost invariably there are too many men helping to move a drill, and that they take too long for it. Another source of delay is preparing the drill for work after it has been moved. It is perhaps just as well to take plenty of time for this, in order to get the drill properly set and adjusted before starting it; but the loss of time between the adjustment and the starting may be said to be about the same as that lost in changing bits, if not a little more.

When the driller takes too long in changing bits, it is largely his own fault, and he should be watched more carefully by the foreman, and, if necessary, instructed. If time is wasted in the moving of the drill, it is the fault of the foreman alone. By a careful timing and balancing of the various processes in drilling, the most competent men can easily be picked out.

In the case of concreting, the minutes lost in the handling of a batch of material from the stock pile to its final position as concrete, often amount to a great deal. Suppose on a small job a half-yard mixer is being used, and it averages for 8 hours 30 batches per hour, or 120 yards per day If it is possible to reduce the time of each batch 15 seconds, the output of the plant will be increased over 14 per cent; or, figured on a basis of 120 yards, there will be an increase of 17 yards, which—at, say, $5.00 per yard—would mean a handsome increase in the daily profits. And still, 15 seconds seems to be almost too trivial a matter for which to spend time and perhaps a little extra money in the way of time-keeping.

Starting with the unmixed material in the stock pile, notice how long it takes the men to load their wheelbarrows with sand and stone; then the time that the material remains in the wheelbarrow, both at the beginning and stopping end of the trip to the mixer; and also the time in transit. If the material is dumped into measuring boxes, note

**ROAD-BUILDING IN PORTO RICO**

A heavy cut on road between Caguas and Humacao. Large hump on left bank of cut to be removed by blasting.

RAILROAD BUILDING IN ECUADOR

the time that it remains in the boxes. If it is dumped directly from the wheelbarrows into the mixer, it is necessary to take the time of mixing from when the first wheelbarrow was dumped until the batch is dumped. The mixer may be said to be the governor of the whole operation; for the men handling unmixed material can handle it no faster than the mixer takes it, and the men handling the mixed concrete can get it no faster than the mixer furnishes it to them. For this reason the observation of the operation of the mixer should be made with special care. It is not our intention to tell how, or to give advice concerning the mixing of concrete; but it is desired to show how, if any time is to be saved, it will be through the saving of seconds in each operation.

If the mixed concrete is to be dumped as a batch into the hopper or hoist, the question of time saving is much simpler than if portions of the batch have to be dumped into wheelbarrows. If, however, it is necessary to dump into wheelbarrows, a basis for the time necessary to empty the mixer can be found only by careful timing and noting the action of the men during the timing.

The time between the filling and the emptying of the wheelbarrow of concrete, will of course vary greatly according to the haul; but here again, careful timing and observation will soon establish a basis from which the most economical manner of distributing the concrete can be made; and exactly the same thing is true of the return of the empty barrels.

All of this may seem to be a digression from the subject of cost getting; but in fact it is merely a discussion of a very refined form of cost getting, and a branch of the subject which has perhaps been given too little attention. When the daily output of a job is up to or above the average, everything looks bright, and no one who is responsible feels overburdened with care. If, however the output falls too low, some glaring cause is at once sought, and the fall of output blamed to some unforeseen circumstance or accident. This is all very well, as accidents affecting output cannot be entirely avoided, and unforeseen conditions will make great differences in performance; but the careful analysis of process cost subdivision will bring about results that will astonish those "practical men" who think that they have got their unit-costs down to the lowest point simply because their output

is generally large and everyone on the work seems to be working to his top notch.

## OUTPUT

The reason for compiling the data for which the time-keeper is responsible, is that, from the analysis of the distribution made, the contractor is able to tell what work is being done with profit; and, if any particular operation shows loss, the analysis will help more than anything else to discover the reason for the loss. In figuring his profit on any work, the contractor must figure on a unit-cost basis, exactly the same as he figures when he prepares his bid. In order to do this, he must have an exact measurement of output. In many classes of work, this measurement is extremely simple; but in others no little ingenuity is required to devise a scheme which will give the information wanted exactly and without requiring much work.

The payment for work is based upon the engineer's estimate. The *monthly estimate* is usually more or less a guess, made simply for the purpose of paying the contractor approximately according to what he has done. The monthly estimate is generally a pretty fair approximation of the exact amount of work done; and the *final estimate* covers everything included in the contract that has not already been taken care of.

The contractor's measurements of work done each day should agree quite closely with the engineer's estimate; but, if the work is difficult to measure, the contractor has many times more opportunity of making errors in his measurement by going over it daily than the engineer has who only goes over it once. A careful consideration of the differences in the amount of estimates will sometimes show the contractor how his estimates can be made to balance with those of any particular corps of engineers, and he can govern his daily measurement accordingly.

There are few measurements in the field which can be reduced to a unit, or rather which can be counted directly. Linear measurements are easy enough to get; the measurement of area is a little more difficult; while the measurements of volume, especially in rough work, are often extremely difficult to make in a satisfactory manner. Measurement by weight is often found to be of great advantage, if proper facilities can be arranged for weighing.

The measurement of drill output is extremely simple. The holes

for any one day's work can be marked as they are finished, and, at the end of the day, all measured; or they can be measured as finished, and their depth taken, and hence the entire day's work is easily determined. This, of course, is a linear measurement; and in the same class would fall such work as laying track, ballasting, grading with a road machine, and the measurement of the work of track and wheel scrapers.

The measurement of quantities whose units are areas is only a little more difficult. Paving, for instance, is very easily measured, the distance from curb to curb generally being constant, and so really reducing the measuring to a linear measurement—that is, the length of the section of pavement laid. Brick laying, while really a cubical measurement, is taken in the same way, the area of the face of the wall laid being taken, and multiplied by the standard number of bricks to any given thickness of wall. This really reduces the measurement for brick laying to a unit-basis, the unit being one brick. Painting and plastering are measured in the same way; and so also is roofing. On road work, plowing and sprinkling are estimated per unit-area; and in quarry work, channeling is so estimated.

The determination of volume on construction work is liable to be very difficult. Take, for instance, the output of a steam shovel cutting through rock. The walls of the cut will be very irregular both in line and in slope, no matter how skilfully the shovel is operated; and the face of the cut is liable to be even more irregular. No absolutely exact measurement can be made; and for this reason it is common practice to estimate the contents of the cars rather than attempt to estimate the size of the pit excavation during any one day. Generally the size of the pit is roughly measured, and the yardage figured from this measurement. It is also figured from the number of cars loaded, and, if carefully done and the estimate of the volume of the cars loaded is correct, both figures should balance at the end of the month with the monthly estimate, which, on account of the large volume measured, can practically ignore such irregularity as would affect the other two measurements. In earth excavation, the measurement is much simpler, because the pit is more regular and the cars can be fully loaded.

There are natural working units that lend great simplicity to calculations of cost—such, for example, as a floor panel in a building, a column, a bridge panel, a pier of masonry, etc.

Another unit of measurement is often obtained through the percentage of a total or of another unit, such as the amount of sand in a yard of concrete. Knowing the mix, a percentage of the total yardage of concrete will be the amount of sand that has been moved.

Care should be taken properly to subdivide the units of measurement. The ordinary unit of concrete work is the cubic yard or the cubic foot. The mistake is frequently made, of estimating the cost of forms and of reinforcement only in terms of the cubic yards of concrete. The cost of forms should be estimated also by the number of feet, board measure. Reinforcing steel should be estimated by the pound.

One difficult kind of work to obtain costs on by the regular method, is the laying of cut stone. A very simple way to obtain this is to paint on each stone a number, and let the time-keeper get the dimensions of the stone after it has been cut, before it has been placed in the wall. Then the stone layer simply records the number of each stone as it is laid.

A check on the measurement of the quantity of the work done is frequently obtained by the measurement of the quantity of the work left undone or of the material remaining in the stock piles.

## COST SHOWING

The object of cost keeping is to furnish accurate and early information to those in authority, both as to where they stand financially on the work, and what necessities or opportunities there are for improvement in economy.

In order to accomplish the object of cost keeping, it is necessary that there be some efficient method of cost showing; and it is essential that the system of cost showing, in combination with the system of cost keeping, shall meet the following specifications:

1. It shall be accurate.
2. It shall be simple.
3. It shall be easy to study.
4. It shall be easy to compile.
5. It shall be capable of being compiled in a very short time after the receipt of the original figures.

It needs no argument to prove that the cost-showing system should be accurate. If it be full of errors, its usefulness is entirely obviated; and 1 per cent of error in it will do a great deal more than 1 per cent

of damage to its efficiency, in assisting the manager to increase the efficiency of the work. There is, however, a limit to the desirable precision of such an affair. The cost of putting in ties on a certain railroad for a certain month, for instance, may have been 7.2143 cents. If the last two figures are interesting from the statistician's point of view, they are utterly useless to a practical manager. If the previous month's performance has been, we shall say, 6.94 cents per tie, this month's figures will have shown an increase in cost of 0.27 cent, which is approximately 3.9 per cent of the previous month's figure. In other words, the tie-placing efficiency has decreased 3.9 per cent. It is very questionable whether the figure 4 per cent, although not quite so precise, would not be rather more useful to the manager than the figure 3.9 per cent; and, personally, the authors would favor the briefer work. The degree of refinement to which these records should be carried, is, in the last analysis, a matter for the individual judgment of the manager himself. The student should bear in mind the folly of unnecessarily elaborate figures.

The second specification, that the cost-showing system shall be simple, is almost as important as the first. If it be not simple, the chances for inaccuracy will be tremendously multiplied. It will take more work to carry it on; and the straightening-out of errors and discrepancies will be so difficult, and will require so much of the time of persons in authority, as to leave them no opportunity to do their other work. Plainly, it should not be necessary for a manager to do a lot of detailed work on cost-keeping or cost-showing systems himself.

Specifications Nos. 3 and 4 are more or less included in specification No. 2. Specification No. 5, however, is also of great importance. Information that is stale is about as useless as no information at all. If you tell a foreman on Monday that the work of his gang for the week ending ten days before was not up to the mark, he will not have much respect for your cost-keeping system; he will certainly not remember sufficiently well the causes that produced his bad work, to remedy them; or he will be able to pick out of the haze of history enough excuses to let himself out of the responsibility of his bad work, and to put his manager at sea as to where this foreman and his gang really stand. It is therefore of prime importance that the arrangement for showing the manager what his costs are, with the salient conditions affecting such costs, shall be so rapid as to be "red-hot" all the time.

The commonest arrangement of cost showing—and the only one ordinarily found at the present day on most contract work—is an abstract prepared on a piece of yellow paper by the time-keeper for the inspection of the manager each morning; and this has so few disadvantages that it would be very satisfactory, were it not that it is impossible from it to compare at a glance the work done, let us say yesterday, with that done previously. It is, however, far better than any other system which lacks any of the essentials indicated above.

## USE OF CHARTS

The best method that has so far been devised is by the use of charts showing to scale the different unit-costs for the various days in the month. Such charts are illustrated in Figs. 7 and 8. They are from the records of the Construction Service Company. One of these (Fig. 7) indicates the cost of channeling rock. It will be seen from the line *A*, that during this month the number of square feet channeled varied from 75 to 375, and that the labor cost varied from a maximum of 62 cents to a minimum of 8 cents. On the 8th, the morning crew did not work, because, as it happened, of severe weather, which accounted for the low output on that day. On the 24th, the night shift allowed the pipes to freeze up. It may be mentioned that the foreman of the night shift, whose name appears in brackets on the chart, has since turned his attention to other fields of industry than channeling. On the 28th, the channeler had reached a point where the cut was frequently filled up by earth that slid in from the side and caused such a large amount of sludge as to cushion the blows of the blade; and the chart shows on that day a high cost, due to the cleaning away of this earth.

The chart illustrated in Fig. 8 is that for steam-shovel work on the same contract of the Construction Service Company. Line *A* indicates the approximate number of yards moved per day. Line *B* shows the pay-roll, ranging from $165 to $310 per day, and including a percentage for incidentals; while line *C* represents the values of the *B* quantity divided by the *A* quantity, and gives the unit-cost in labor per yard for excavating and moving rock. It will be noted that the Sundays are skipped. These came on the 5th, 12th, 19th, and 26th of the month. There were some men employed on each of these Sundays; but their time was so distributed over the rest of the month as not to show for the Sundays, as the steam shovels did not work on that day.

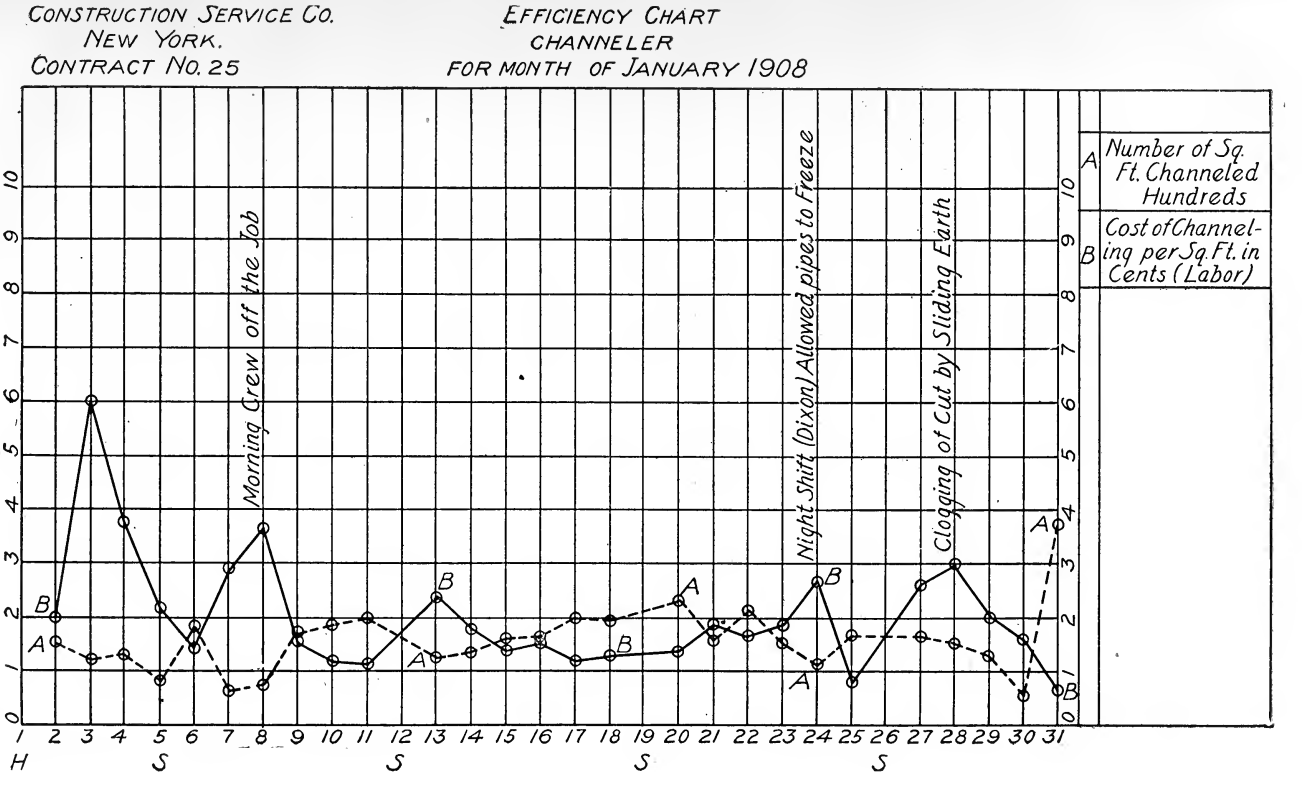



Fig. 7. Efficiency Chart Indicating Cost of Channeling Rock.

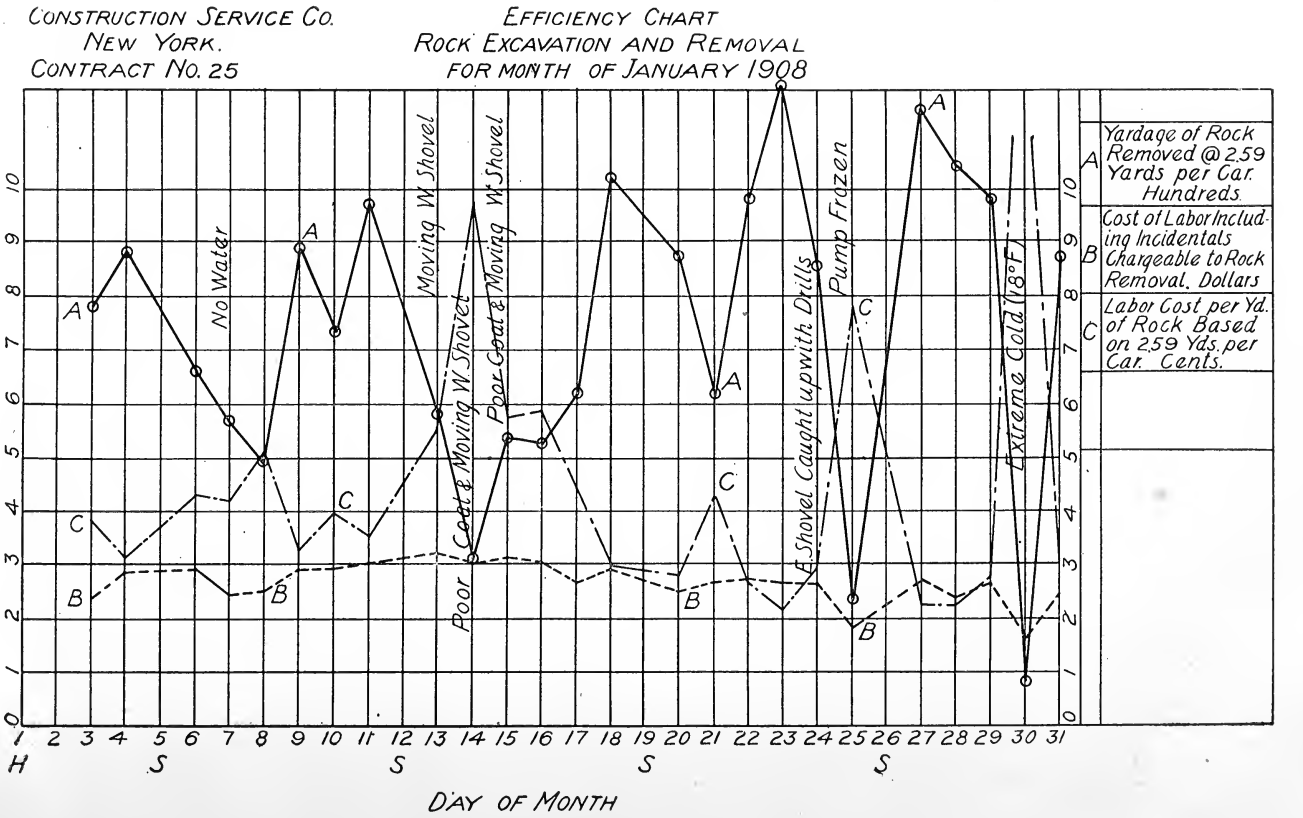



Fig. 8. Efficiency Chart Showing Costs in Connection with Steam-Shovel Work in Rock Excavation and Removal.

These charts are of a size to be filed in one of the standard loose-leaf books, and their range is from zero to about 12; thus it is possible to show any quantity to scale for any day in the month. This company has not found it of advantage to plot more than 4 lines on any one chart.

Charts such as these may be marked each morning by the time-keeper upon a tracing prepared for this purpose; and at the end of the month the lines connecting the points may be inked in, and the chart blue-printed and the blue-print filed in a convenient place for immediate reference.

There are several ways of working out the unit-cost from the figures, such for example as:

1. Performance per time unit
2. Performance per dollar;
3. Cost per unit of performance.

The first of these is not, properly speaking, a cost statement, although it is a function of a cost statement and for certain purposes is more convenient. The number of feet of rock drilled per drill hour, is a very convenient form for record.

When drilling under conditions of snow and ice, more muckers have to be employed than at other times. If the cost of mucking is included in the cost of drilling, as it frequently is, the true index of how well the drills are getting on is the number of feet per drill hour, rather than the cost of the operation to the contractor.

The second method is the reciprocal of the third. Other systems will suggest themselves by virtue of the peculiar requirements of each case in practice.

**Checking by Charts.** A great advantage of the chart system of cost showing, is that it acts as an automatic check upon the cost-keeping system in general. As indicated earlier in this volume, it occasionally happens that a punch-card is not turned in, or the time-keeper fails to get certain data. This is immediately discoverable by the gap on the chart, and thus the chart acts as a check on the cost-getting department. This will not entirely obviate the necessity for inspection to ascertain whether the time-cards are properly kept and the work is properly done.

The showing of costs should be made *daily* for the men immediately identified with the field work; they should be made *weekly* for

the general manager, and *monthly* for the home office. These monthly office reports are sometimes valuable in the planning of the financial arrangements for the work. On a job involving, say, a pay-roll of $5,000 a week, with monthly estimates, early information as to performance over the month is of very great value.

Showing the men certain charts and records will serve to increase their interest in their work, but this should not be overdone. It is as well that the men should not know the actual cost of their work to the contractor in dollars and cents. If, on the contract price, the contractor is making a handsome profit, the men want more money. If the contractor is not making a handsome profit, the men are apt to think that they are on a losing job, and become discouraged accordingly. The economy of the contractor's work should be private information, since it might do him considerable damage by becoming known to competing contractors. The charts showing the performance per unit of time, however, are not subject to the restrictions above mentioned.

## COST KEEPING

In the foregoing there has been nothing that is a part of the regular bookkeeping, with the exception that part of the time-keeper's records are necessary to the bookkeeper. It should be appreciated at the start, that the bookkeeper's work is of great importance, that it cannot be superseded by a cost-keeping system, and that it should not be divided up with the cost-keeping system. The scoffers at cost analysis are inclined to take the ground that a bookkeeper, a cost-keeper, a cost-analysis engineer, are more or less clumsy substitutes for managerial intelligence; and they point to the proposition that in the last analysis it should be easy to let the office boy run the job with a textbook at one elbow and a calculating machine at the other.

It is insisted upon at the start, that cost keeping is as important as bookkeeping, but that it has an entirely different function; and in applying cost keeping to construction work, it is very important that a distinct line of demarcation be drawn between the two branches.

Another error that is frequently made by antiquarian students, men who are studying old methods of engineering and construction rather than those of to-day, is that a cost-keeping system is assumed to be complete by the man who runs it, when he knows how many feet of hole his drillers are able to average per hour, per day, or per

week. The cost analyst will point to the fact that in the literature of the subject many false statements are made as to the costs of certain items of work, and will show that no allowance has been made for depreciation, repairs, etc., not to say profit, interest on the contractor's money, and a host of other things. The student is warned that a proper cost-keeping system must of necessity take into consideration *all* the items of cost on the job; and, further, it should take them into account with such detail that it will be a real, living help to a man in estimating future costs on similar work.

Now, as a general thing, the essential similarity of items has been lost sight of when these items are parts of work which is not generally dissimilar. For example, the item of earthwork in the construction of a large dam may be very similar in its essential cost to, and may be of the greatest use in assisting a contractor or engineer to figure the cost of, earthwork under similar climatic conditions on a railroad embankment; yet those who are most interested in the subject are inclined to classify dams as an entirely different sort of structure from railroads. The designing of a dam is a different matter from the design of a railroad; but to build one will often involve the same kind of tools, the same kind of machinery, the same kind of men, the same kind of "horse sense," and the same general principles of construction, as to build the other. Therefore, if his costs are properly subdivided and intelligently kept on one kind of construction, the contractor or engineer will be materially aided, not only in estimating the cost of the work upon the other, but in being in close touch with his work after he has started.

Every construction organization ought to have a schedule of standard items which may be called *ledger accounts*; and its books ought to be kept in such a manner that the records of the total and of the unit-amounts for these items on past work and on current work may be immediately available for the benefit of its officers. No two contractors will have the same arrangement for distributing cost; no two will have the same items for the accounts; but there are certain fundamental items that will come into use on almost every large piece of work, and some of them have a peculiar significance, and should be treated with special care.

**Estimates on Ledger Items.** In making estimates it is important to have this list in sight, in order that important items may not be

omitted. Such a list, which will cover a large portion of the ordinary charges, is here given:

1. Gang Labor:
   (*a*) Hourly rate;
   (*b*) Monthly rate.

The men who work by the month are apt to have to spend a good deal of non-productive time, on account of weather conditions, etc.; while the men who are on an hourly basis, as a general thing, do some profitable work whenever they are paid. It is feasible to figure a good deal more closely on the cost of work for those men who have practically no lost time to be taken care of, as *emergencies* or *incidentals*. It will be noted, also, that the cost and the time of hourly and daily men can be figured and charted day by day; whereas it is impossible to know exactly what the charges will be for labor that is paid by the month, until the end of the month. In order to make report charts showing cost as completely as possible, it is a frequent practice to add a certain percentage to the cost of the known items, to cover the so-called *lost foremen's time;* and to make at the end of the month a correction of a greater or less size, in order to make the cost-keeping end tally with the bookkeeping end of the work.

2. General Labor, etc. This item will comprise the labor of the men who have something to do with more than a few parts of the work. A watchman's time is not spent in drilling, or on a steam shovel while it is running. Nevertheless a proportionate part of his salary should be divided among the different branches of the work. Sometimes this will be a very small item, sometimes a large item. For example, if a steam shovel is excavating 30,000 yards of material per month, the watchman's unit-charge to excavation may be very small; but if the shovel is tied up for nearly the whole month, the charge per unit for watchman's time may be alarmingly high. This is one reason why unit-cost and total cost should always go together. A blacksmith's time, part of which is spent in sharpening drills, need not be all chargeable to drilling, because he may spend a good deal of time in repairing the steam shovel or fixing hand tools, etc.

3. Overhead Labor. Clerks, bookkeepers, messengers, office force, and General Manager are ordinarily included among the items of *overhead charge*, as well as salaries of general officers.

4. Overhead Materials. In this classification, there are

included stationery, office furniture, supplies, etc. When the office furniture is disposed of upon the completion of the work, its value should be credited upon this item.

5. Overhead Incidentals. These may include various items, such as telephone, office rent, telegraph messages, express charges on incidentals not directly connected with plant, etc.

6. Preparatory Costs. These include the cost of getting ready to do the work, and, depending upon the nature of the job, may include any or all of the following items:

(*a*) Temporary roads;
(*b*) Temporary trestles;
(*c*) Clearing and grubbing;
(*d*) Snow removal and drainage;
(*e*) Traveling expenses to job;
(*f*) Preliminary estimates, calculations, and surveys;
(*g*) Freight and handling of materials to and from job;
(*h*) Freight on preliminary supplies;
(*i*) Handling of preliminary supplies;
(*j*) Licenses and premiums on bonds, etc.
(*k*) Legal expenses;
(*l*) Loss on initial operations;
(*m*) Right of way and cost of site;
(*n*) Sheds, storehouses, and other temporary buildings;
(*o*) Tools, less final value.

7. Supplies. These are chargeable F. O. B. the job, or at the railroad station nearest to the work. They include all supplies for carrying on the work, as distinct from *material,* including explosives, coal, oil, waste, etc., and may include a *charge for water.*

8. Interest and Depreciation on Plant. This item is variously estimated by different people, and may vary greatly. It is impossible to establish an absolute rule; but on the average contractor's plant, it may be stated that $\frac{1}{10}$ of 1 per cent per working day is a very fair general average figure. The average steam shovel, for example, will work perhaps 200 days, under favorable weather conditions; and on this basis the interest and depreciation charge will be 20 per cent per year, and is not far from a fair figure. Some contractors allow 33 per cent per year on such material as road machinery, including crushers, steam rollers, etc. This is a little high, provided that a reasonable charge is made for repairs.

9. Repairs to Plant. How much money it takes to keep the equipment in proper condition for performing efficient work, is a

question on which the limits of space prevent a detailed discussion. On such a machine as a standard-gauge steam locomotive in constant operation to the limit of its capacity, repairs may run as high as 20 per cent per year; and on a rock drill the repairs may be 50 per cent or more per year.

10. Rent, Stumpage, etc. The item of *rent* includes the rental of ground and the storage buildings, if any, outside of the office expenses. *Stumpage* is the cost of standing timber, the purchaser being privileged to leave the stump after cutting down the tree.

11. Materials of Construction. These are chargeable F. O. B. the job, or at the railroad station nearest to the work.

12. Handling of Supplies.

13. Freight, when not included in item No. 11 or No. 7.

14. Unloading, Hauling and Storing Materials and Supplies.

15. Re-handling Materials and Supplies.

16. Interest on Cash Capital Exclusive of Plant.

17. Taxes and Insurance on Property (including boilers).

18. Accidental Insurance, to protect workmen and the public.

19. Advertising, Medical Expense, and Charity.

20. Discounts on Bonds, Warrants, or Notes.

21. Contingency Labor.

22. Contingency Materials.

23. Contingency Supplies.

24. Cost of Finding and Recovering Lost Freight and Supplies.

25. Profit.

## COST REDUCTION

The ultimate aim of cost analysis is economic efficiency; and any system or method of cost analysis which does not result in the lessening of the total cost per unit of work performed, must necessarily be a failure.

After the costs on work have been partially analyzed, it becomes the province of the engineer to introduce methods and devices whereby the expense of obtaining the various data may be more than offset in the general economy of the work. It was long ago realized that shop practice could be economized by methods of systematization; and we have an early instance of the appreciation of this fact in the story

of the struggles and methods resorted to by James Watt in the construction of the early steam engines. The troubles arising from incompetent workmen, drunkenness, and the necessity of doing work in different parts of the country far removed from headquarters, were as real then as they are now, with this disadvantage, that in the eighteenth century the press, the telephone, and the professional schools had not reached a development admitting of intelligent co-operation in the attack upon this problem.

Within the last score of years it has been found that cost-analysis applied to shop work problems gives most amazing results. When the piece-work system was introduced, it was believed that the final solution of the problem had been attained. The men were then placed upon the footing of contractors. A man got so much pay for accomplishing so much work; and it was most clearly to his interest to accomplish the maximum of work in order to get the maximum of pay. It was immediately evident that the good men would soon show such a contrast to the poor men on the work as to inspire a constant rivalry, thereby resulting in a very much higher output. In order that the desire to accomplish more work should not interfere with the quality of the work, all materials were systematically and rigidly inspected.

For a good many years the piece-work system flourished, and it is still flourishing as compared with its predecessors. It is vigorously fought by trades unions and by the less able among the men. It is tolerated by those of mediocre ability, and it is heartily endorsed by the most skilful. In order to remove the resistance of labor unions, a modification of the piece-rate system, known as the *bonus system*, has been devised. It will be described in a subsequent paragraph.

Remarkable development has been achieved in the shop by the most brilliant work on the part of the men who have applied cost analysis, favored by the fact that in the shop one has conditions of work which are practically invariable from day to day. It is possible, then, to compare the work done per unit of time in the morning, with the work done per unit of time in the afternoon, or for each hour in the day, and thus to determine the effect of fatigue of the operators upon their efficiency and the effect of such specific influences as the character of artificial light, the grade of steel in tools, and even the economic value of providing reading rooms, white-enameled lavatories, and

recreation for the operatives. To cost analysis has been largely due the development of the special high-speed steels and an amazing number of improvements in machinery, entirely aside from the stimulus and education of the workmen.

In field work, however, comparatively little has been accomplished in the world at large along these lines, not because the opportunity is lacking, but because certain of the difficulties appeal more glaringly to the pioneer in the field, and offer some peculiar discouragements. The conditions are not uniform from day to day. The locus of the work is changing, the weather is variable, and a very large number of external agencies will be continually interfering with the scheduled regularity of the work. The method or process whereby a piece of work can be done more economically, may be instituted at just the time when some apparently trivial variation of the weather, or breakdown in a water system, or interruption in train service, may produce an entirely opposite effect which will more than nullify the advantages obtained from the improved process or method, and will sometimes cover a period of a good many days and possibly weeks, making it appear that the improved method is not only a failure but a dragon in disguise.

Field work is constantly presenting obstacles and difficulties which have to be met and fought, calling for emergency judgment on the part of the men in charge and on the part of all the men on the work to a greater or less extent; and here alone is one of the chief reasons why a contractor comes to depend almost exclusively upon the personality of his superintendent or foreman, to the exclusion of systematic analysis.

It is abundantly demonstrable that when results are properly charted, and when a careful record is kept of the causes of interruption and the extent of the accidental obstacles, the problem becomes much simplified. It is astonishing how intimately a manager may come into touch in a short time with the obstacles to his work, and with the most efficient methods for their removal, by means of proper reports and cost analysis, and especially by the intelligent use of charts.

**Effects of Weather.** The principal obstruction to economical construction work in the temperate zone, is due to *rain*. If it is raining at about the time when the men come upon the work, they will

rarely fail to retire to their homes or to some point so far from the scene of operations as to make it difficult if not impossible to get them back upon the job if the weather should clear.

If a rain comes on in the noon hour, they generally leave and do not return to work. If it should start to drizzle in the middle of the afternoon, and the men are under fairly good discipline, they stand a very good chance to stay the day out rather than miss getting a full day's pay.

Next to rain as an obstacle is *freezing weather.* On concrete work, if the concrete is laid at temperatures below 22 degrees, and particularly when a slow-setting brand of cement is used, special precautions have to be taken, and even then the work is liable to be rejected. For work in which steam engines are employed, as dinkeys, steam shovels, steam drills, etc., continued cold weather is likely to result in the freezing of supply pipes, the freezing of valves, and the breaking of pipe connections, necessitating a good deal of frost protection and a well-disciplined and well-handled gang of pipe-fitters under a responsible foreman charged with the express duty of keeping the water lines clear. In very cold weather—say below zero—the freezing of water will seriously interfere with the economy of the work on the water end alone. Where steam drills are used and the weather is exceedingly cold, the steam from the drills blown upon the men condenses and freezes upon their clothes, involving great inconvenience and suffering. Under such conditions the men will not work so many hours per day as otherwise, and frequently they will not work at all at critical times in the progress of the work, to the great detriment of economy.

It has been observed that a combination of stress of weather a few hours before the coming of the paymaster seems to be more discouraging than at any other time, and it is seized upon as an excuse to quit work.

In very windy weather, more coal is burned than at other times; and sometimes a boiler which is capable of running seven or eight drills in ordinary weather will not be able to furnish steam for more than 70 or 80 per cent of this amount in the high, cold winds.

For the above reasons it is essential to keep a record of the temperature and weather.

**Accidental Conditions.** Besides the weather, there are a host of

accidental conditions that may arise to influence the economy of the work and complicate a precise study of the performance. Some of these, named at random, are:

1. The blowing-out of the gasket in a main water supply pump.
2. A shipment of poor coal.
3. The wrecking of a trestle.
4. A derailment of cars.
5. The breaking of machinery on a shovel.
6. The burning-out of a boiler, due to carelessness on the part of a watchman over night.
7. The non-arrival of necessary and important material.
8. Irregular blasting, due to irregular spacing of drill holes, or to bad loading, or to poor detonators or a poor exploding machine, or to irregularity in the character of the rock itself.
9. Erratic action on the part of one or more of the men, due to drunkenness, ill-temper, or general contrariness.
10. Errors on the part of foremen in co-operation, some of which are not detected in time to be eliminated.

In working out any special problem, care should be taken that such accidental causes affecting performance—whether they decrease the performance or, as may happen, increase it—should be carefully noted and be a part of the regular report on the work. These features of a report ordinarily are ignored as being unimportant, but they are of the utmost value to the success of the work.

## STIMULATING THE MEN

The art of persuading a man who is turning out 500,000 foot-pounds of work in ten hours, to turn out 800,000 foot-pounds of work in ten hours with a trivial increase in pay, is on its face difficult; but is by no means impossible, and a list of some of the ordinary means of doing this should not be out of place here.

1. **Watching the Work.** If, on the average work under the observation of a foreman whom they know, the men are made to realize that their individual performance is being watched and recorded by someone who is above and beyond their own foreman, there will usually result an increase in performance of from 10 to 20 per cent per man; and particularly if a tab is kept upon the performance of the gang as a whole, the foreman will add his own stimulus to that applied by the men themselves, resulting in highly inceased efficiency.

On such work as teaming, where teams are hauling earth along a road for a considerable distance, a punch-card is very valuable.

The driver knows that the time of his trip is being recorded and compared with the time for the same work done by other drivers; and it has the effect of concentrating his mind upon his performance, which in itself causes him to use more care in cutting down delays and keeping his team up to their work.

In the operation of drilling, most valuable results have been achieved by giving each drill runner a card on which, at the completion of each hole, the time of the finishing of the hole is punched; and also the time of starting the new hole, in the same way. This card will then show the length of time that it took to drill the hole, and the length of time required to move his drill. He will be stimulated to move quickly, which in soft rock is an exceedingly important element of the drilling work, and he will be stimulated in the effort to get his holes down rapidly.

Where earth or rock is being loaded by steam shovels and hauled by dinkey trains, great economy can be arrived at by providing each dinkey runner with a punch-card or a report card on which he indicates the time when his train left the shovel and when it returned again to the shovel. This card then indicates the time for a round trip, and his mind is constantly being stimulated to look out for causes of delay; and, if he is at all conscientious, as most men are, he will instinctively attempt to make the best time. Some remarkable results have been achieved by this means alone in recent work.

When concrete is being mixed by hand, if a record is made of the time when each batch is finished, there will inevitably be an increase of activity of all the men in the mixing gang.

2. **Discharges.** The principle of natural selection of the men can be very advantageously applied. Where the supply of labor is adequate, it is advisable to make a rule of discharging a few of the poorest men every few days, taking on new men to fill their places. This necessarily results in an increase of the ability of the average men on the work, and it gives a healthy spur to the men who are not discharged. In carrying this method out, it should be done judiciously and with care to avoid discharging good men, lest the discipline of the work be interfered with. Any man who is not willing to do his best, or who is caught loafing deliberately, is an economic disadvantage to the work, and should be allowed to go. Likewise, any man who with good intentions is so dull as to hinder the progress

of the work, should not be retained because of his good intentions alone.

3. **Bonus Systems.** An immense advantage can be counted upon by the employment of a bonus system, of which there are a good many; and it should be said at the start, that a bonus system may, although it probably will not, be opposed by labor unions. The general idea of a bonus system is to place the men upon a contract footing whereby they will be guaranteed a minimum wage, and more money than the minimum if they perform unusually good work. A refinement of this system may be applied where the men receive less than the guaranteed minimum if their work is noticeably poor. Where this latter arrangement should be applied, will depend largely upon the local conditions; and this feature is the one that is peculiarly obnoxious to the labor unions. Where the supply of labor is adequate, it is usually better to discharge the inefficient men than to attempt to work them under a depressed rate.

On a recent piece of work, the steam drills, of which there were 14, were averaging 4 feet of hole drilled per drill hour, the drillers were getting 30 cents per drill hour, and helpers 18¾ cents. For a period of ten days the drills were kept under the personal supervision and instruction of the expert in charge; and at the end of that time a bonus of 2 cents per foot for everything above 70 feet in 8 hours was offered to the men. On this basis no one could get a bonus unless he did 100 per cent better than the average previously attained. Exceedingly cold weather intervened, preventing a good deal of drilling; but within two weeks of the return to normal weather conditions, the average drill output rose to over 6 feet per drill hour, and one man obtained the remarkable record of 142 feet in 9 hours, or over 15.7 feet per drill hour. On this work a careful record was kept day by day, of the performance of each man; and the men who had a consistently low average were gradually discharged, thereby helping out the bonus system. The men were also under more or less constant instruction, and therefore the improvement was not entirely due to the bonus system.

A further modification of the bonus system is advisable in some cases, where an extra bonus is given for exceedingly high performance, such, for example, as paying the men an extra cent bonus, making 3 cents above, say, 90 or 100 feet per 8 hours. It is well, however, to

apply this modified arrangement only after there has been an elimination of the poorest men. When possible, the payment of bonuses should be made at very short intervals, and not left to a monthly settlement.

4. **Bulletin Board Posting.** Posting upon a bulletin board in the storehouse or office, of the records of performance accomplished in different parts of the work day by day or week by week, is a very valuable adjunct to the other methods of stimulation. The methods above indicated will keep the men on the *qui vive* during the day. A very valuable improvement can be instituted if the more intelligent among them can be led to think about their work after working hours. This must necessarily be done in rather a subtle way. Posting records at the end of the day's work so that the men see them on their way home, will do a great deal toward keeping the subject alive until the next morning. When the men have been led to a state where they discuss with each other the methods of improved efficiency, for the following day amazing results can be counted upon.

5. **Gang and Team Work.** If a certain number of men have been working together under one foreman on one particular piece of work, they come to know each other's methods and their foreman's methods intimately; and they necessarily will become very much more efficient than when they are shifted from gang to gang or when they have to work under different foremen. If the record of the performance of each individual gang can be obtained, and the men, as well as the foreman, are acquainted with the record, a spirit of rivalry between the gangs can be developed which will add greatly to efficiency. In making such a record, inasmuch as the gangs are likely to vary in size, it is necessary to have a unit of performance that will be independent of the number of men in the gang. It will be found that, shortly after the application of this principle, the men are themselves making suggestions as to improvements in method; and frequently their suggestions are immensely valuable.

6. **High Pay.** Some contractors have found it economical to pay a little more than the prevailing rate of wages, thereby attracting to their organization the best of the labor available. As a general thing, a man is perfectly willing to do 10 per cent more work for 5 per cent more pay per hour; and the difference in men is so great as to

make it more than well worth while to secure the very best of the labor obtainable.

7. **Prompt Pay.** Men will work very much more contentedly when they can count upon their pay with promptness and regularity. There is nothing that demoralizes a piece of construction work more than the postponement of a pay-day. Special care should be taken that each man's pay is accurate. A man will seldom be overpaid unless there is "graft" on the job, but it sometimes happens that through errors on the part of the time-keeper or bookkeeper a man's pay is short, much to the agony of the man himself.

8. **Early Hours.** A good deal of money is lost by the men not starting to work promptly at the commencing hour, and by quitting before the final hour. On a recent piece of work that had to be drastically reorganized, an entire blasting gang rested on their shovels for over one hour, because their foreman had decided to quit without notice, and the man who was supposed to be in charge of the work arrived late himself, and was detained at the other end of the job. On this particular piece of work, it was not the habit to blow a whistle at the commencing or the quitting hour, and the men started work in the morning and quit work in the evening according to their own time-pieces. It was noted that nobody on the whole job quit a minute after he should have quit, or started a moment earlier than he was paid to start.

In factory work it is feasible to have all the men go through a gate which is closed one minute after the hour and not opened again for perhaps 25 minutes, so that, if a man is two minutes late, he loses a half-hour's pay. This has the merit of not working injustice to anyone, and, after being instituted, seems to be accepted by the men with a reasonable degree of contentment. It is not easy to start a strike because some men lose their jobs from being late.

Such a system as this, however, is practically impossible on outside contract work; and while it may be feasible to institute a modification of the time clock method, it is not known that this has yet been successfully done. Probably the most satisfactory way of insuring prompt arrival of the men, is to measure the output of each gang and make each foreman responsible for it, thus giving him a personal incentive to get his men on the job promptly.

9. **Enough Foremen.** It is necessary, in any organization,

to have the chain of responsibility lead through a sufficient number of foremen; otherwise a superintendent or supervisor will find himself "spreading out too thin," and will be attempting to perform a lot of work that should be done by a foreman. One superintendent can supervise the work of 20 or 30 foremen with a favorable layout, and each foreman can supervise the work of from 10 to 25 men. If, however, there be more gangs than there are foremen, the superintendent will find himself trying to play the part of foreman in instructing the men, and not able to do his own work, which is to instruct and supervise the foremen. In the matter of drilling, a number of able managers are not in favor of having a foreman over the drills. It is calculated that by substituting a boy to keep the records of the drilling, and putting bonuses on the drills, the difference between the pay of a foreman and the pay of a boy is saved, with no appreciable loss in performance.

There are strong grounds for the opinion that there should be no process, such as drilling, without a foreman, where the work is on a large scale. When 10 drills are working, they will employ altogether 20 men on the drills, a number of muckers clearing the ground, and a pipe man. The work of these men cannot fail to be improved by their being at all times under the watchful eye of a man to whom they are responsible for the quantity and quality of their work. Aside from this, if the foreman is an expert driller, the instruction that he can give to the less able of the drill runners will be worth ten times its cost.

The same argument applies to all processes in the field.

10. **Education on the Work.** As a general thing, men who take money for their labor are more than willing to deliver a square deal to their employer; and it will almost invariably be found that the more familiar a man is with the difficulties and possibilities of his fellow-workmen, the more efficient he will be himself. For this reason it has been found highly satisfactory, in some lines of work, to change the men around on the job. In a certain concrete building 12 stories high, the upper stories were built in a small fraction of the time required for the corresponding lower stories. The greater part of the extraordinary increase in efficiency was attributed to the fact that the men were so educated that a man at the top of the building knew how the men at the mixer and in other parts of the job were doing their work, and knew that the superintendent in charge was measuring the speed of

the deliveries from the hoist. The disadvantage of this method is that it takes a long time to work up the efficiency. It is, however, an admirable method for disciplining an organization.

**Discipline.** To the practical man, or to the intelligent student, there seems to be no necessity for arguing in favor of *discipline* as an essential to economical field work; but so large a percentage of contract work in the field is badly disciplined, and the general principles seem to be unknown to so many field organizations, that a brief statement of them appears to be called for in this volume.

By *discipline* is meant the cultivation of a spirit of:

1. Co-operation;
2. Obedience;
3. Responsibility;
4. Personal loyalty.

The subject will be discussed on the basis of *reorganization of work*, because here the chief difficulties are met.

The three types of organization that are most clearly defined in the way of discipline, are those of a *military nature, railroad work*, and *factory work*.

On construction work, it is not feasible to introduce a military form of discipline. In the first place, the penalties of the military service are not permissible; and in the second place it is not usually practicable to have so thorough a system of distribution of responsibility; while in the third place the same men are not here together for a long enough period to make military discipline practicable.

In railroad work a man is usually employed for a long term of years, on rather small pay, with a large chance of promotion. From the day of his initiation on the work, he is impressed profoundly with the necessity of protecting lives and of keeping trains moving all the time; and, in a short time, he comes to the frame of mind in which his pay, his personal convenience, and his personal prejudice are subordinate interests. The initials of the superintendent on a little slip of paper are sufficient to make him do almost anything within the limit of endurance; and, as a general thing, he does it ungrudgingly (but not uncomplainingly), and with a cheerfulness that is in many respects astonishing.

Such a degree of discipline is entirely feasible on any contract work of long duration, and it should be obtained if economy is desired.

It is not possible to institute successfully radical reforms and methods, without first securing good discipline on the work; and when work is badly disorganized, the discipline should be the first point of attack.

It is necessary to have, first, a system of locating responsibility. If a dinkey becomes derailed, if the spacing of drill holes be erroneously made, if a steam shovel be out of line, if the wrong methods of loading be pursued, if a pump be out of order, if necessary material or supplies be wanting, if the pipes freeze up, if, in short, one hundred and one little things happen that cause confusion on the work, it should be possible to find someone who, by some crime of omission or commission, is responsible for the trouble, and who can be made, in some degree at least, to bear the brunt of it. The only man who seems destined to be entirely free from the consequence of his mistakes, is the clerk of the Weather Bureau.

The organization should be laid out from the bottom upward, rather than from the top downward. The laborer is responsible practically for carrying out the instructions of his foreman to the satisfaction of his foreman and of no one else, and for this reason he should not work under the impression that anyone except his own foreman is likely to discharge him, to criticise him, or to praise him. If his foreman be the right sort of man, the laborer, with his dozen associates, will have at heart, besides the interests of the work, a strong feeling of personal loyalty to the foreman; and this feeling will be reciprocated by the foreman. If a foreman be noticed vigorously complaining that the men he has to deal with are inefficient, incompetent, and a disgrace to civilization compared to the men he had to work with some years before, he may as a general thing be put down as a "blow-hard" and of little value to the organization. The most successful are usually the ones who are ordinarily quiet, cool under emergency, and yet of sufficient determination to inspire among the men a wholesome respect for them. A man who loses his temper on the work for any reason, does not, as a general thing, make a good foreman or superintendent.

The relations obtaining between the men and their foreman, should obtain to a more marked degree between the foreman and their superintendent. Briefly stated, every man on the job should have to look for orders from one man and only one man; and he should be responsible to that man for the satisfactory performance of those orders.

Conflicting orders can be avoided only by systematic compliance with the rule just above outlined.

It sometimes happens after periods of financial depression, or as a result of special conditions, that it is feasible to reduce the pay of a good many men on the work. This should always be done with great care and after an intimate knowledge has been obtained of the personalities of the men affected. As a general thing, if you cut down a man's pay 10 per cent, you will cut down the work 20 per cent, at least for a time; and it frequently happens that after such a pay reduction, small, petty depredations on the work are committed. Articles get stolen; machinery is damaged by "sore heads." It is usually unwise to reduce the pay of a few men. As a general policy, where a small percentage of the working force is to be affected, it is better to discharge a few men outright, and endeavor by economic methods to increase the output of the others.

Differential pay is a prolific source of trouble, and it is very common. By this is meant the payment to different men of different rates for the performance of the same work. The men who obtain the less pay think that their pay ought to be raised; and the man who gets the most pay can in no probability appreciate the fact that he may be over-paid. Rather than cut his pay down, it is well, if possible, to put him at some other class of work.

It is often necessary for economical reasons to place men who have been paid by the month, upon an hourly basis; and even when by this they average rather more than they formerly received, it usually causes discontent. Any man likes to know how he is coming out at the end of the month regardless of the weather, and it is an additional source of anxiety to him not to know what his pay envelope will contain. When he keeps his own record of the hours worked, he is likely to disagree with the time-keeper, and this can lead to a good deal of disaffection and dissatisfaction.

A frequent cause of disaffection on work is due to the habit too often indulged in by time-keepers, of gossiping with the men. The time-keeper and the storekeeper necessarily come into contact with a very large percentage of the men every day; and if the time-keeper particularly be disposed to gossip, he has abundant opportunity to gratify his desire, and can produce a great deal of trouble. For this reason the general character of the time-keeper should be carefully

scrutinized before employing him; and he should be cautious, when making his rounds, to confine himself strictly to business. If the men on the job know as much about the work as the General Manager, if they know all the ins and outs and ups and downs of the contract, they necessarily discuss it among themselves, and a great deal of restlessness is produced, which is very difficult to stamp out, because, by the time it has reached a pronounced stage, the men have learned so much about the politics, as it were, of the job, as to interfere with the discipline.

If there be dissensions at headquarters, if the parties that control the work are at war, and if the methods and performance of the manager or superintendent be not absolutely satisfactory to every one of the officials, nothing can be worse than to let a suspicion of this matter get around among the men. How a general manager or superintendent can prevent this, if an officer be disposed to talk, is a problem that no attempt will here be made to solve. In reorganization, such a condition is one for which the manager should be continually on the alert, and he is advised to be suspicious of the time-keeper and storekeeper.

**Labor-Saving Devices Involving Plant.** If the men are in a reasonably good state of discipline, it is feasible to make changes in the layout involving special apparatus or plant; and in deciding upon such measures, a question arises as to how much money it is justifiable to spend for a new plant. A piece of work under reorganization is ordinarily a piece of work that is more or less in financial difficulties, and the purchase of plant for the economizing of the work is usually looked upon by the officers as a dangerous move. Particularly is this the case when any changes of this kind turn out to be unsuccessful. A small amount of money wasted on special apparatus is always in sight—at the scrap heap, if nowhere else—whereas a good deal of money wasted in fruitless labor can be easily lost to view.

If the amount of saving on a certain operation by the installation of special material be sufficient to pay for this material in a few weeks, the purchase of the material can be immediately justified, and the cost of the apparatus can be charged as *current expenses* to be shortly recovered in the economy of the work. Where expensive and heavy machinery is to be installed, however, the matter should be gone into with the greatest care and detail.

A few of the articles which come within the class chargeable to *current expenses*, are:

1. The use of water jets for increasing the speed of drilling in soft rock.
2. The use of hickory wands for stirring up sludge in drill holes, and increasing the speed of drilling.
3. The use of special explosives and good exploding machines, and of loading tubes for blasting.
4. Small grading machines for spreading earth and macadam.
5. Special wheelbarrows or carts for moving material.
6. Special small tools for the blacksmith, including a trough in which he can set his bits to be hardened, with the points in the water.
7. A sufficient supply of picks and shovels.

Some of the items of plant that may be classed in the other category, are:

1. Special wagons and scrapers for hauling earth.
2. Concrete mixers especially adapted to the work in hand.
3. Derricks.
4. Locomotive cranes.
5. Cableways.
6. Bit-sharpening machines.

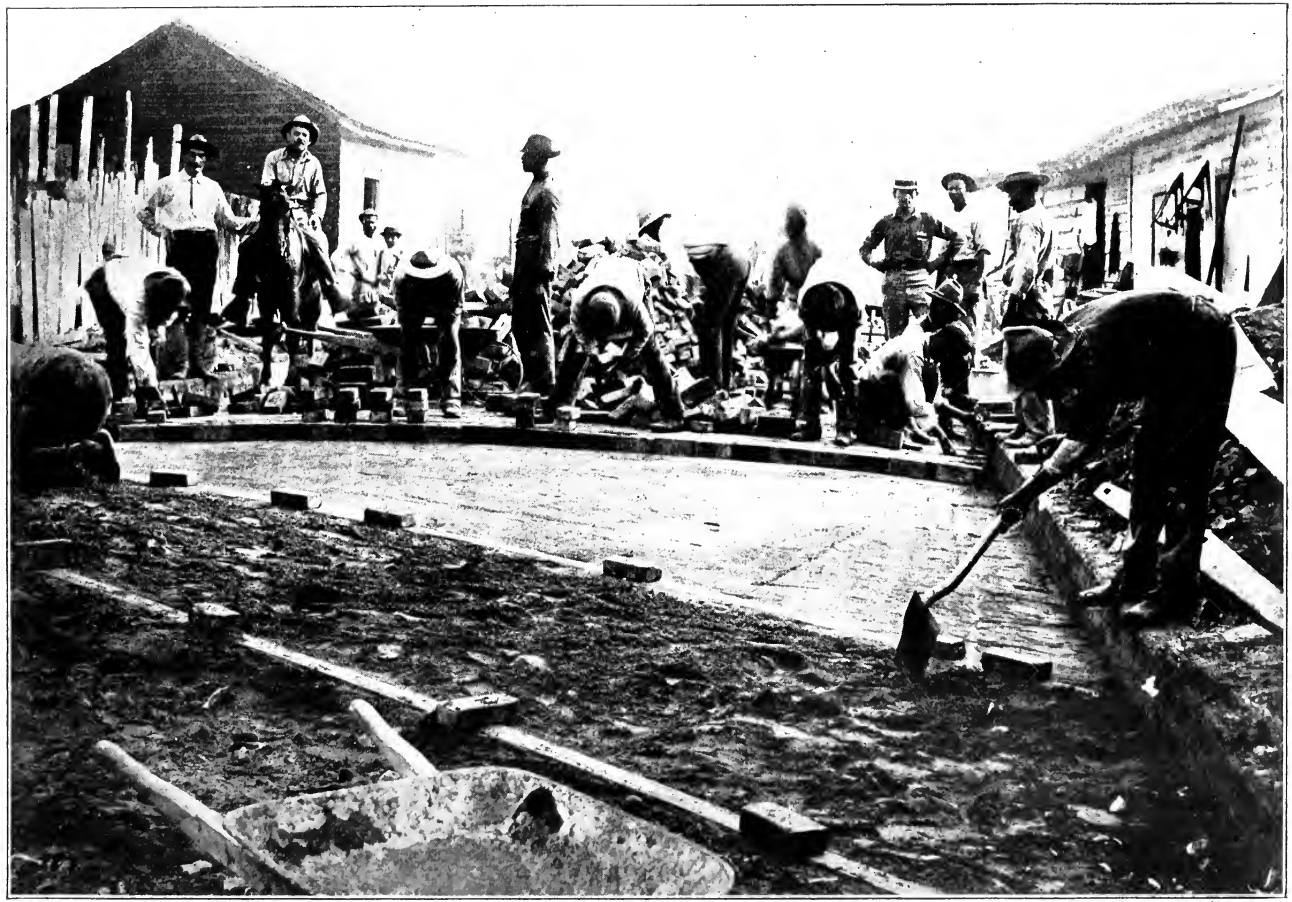
**Labor-Saving Devices Involving No Plant.** Where the labor preparatory to introducing the improved methods is considered, it should be taken as equivalent to a plant charge as affecting the interest of the contractor. If, for example, it has been the practice to drill and blast immediately in front of a steam shovel on rock excavation, and it is desired to have the drilling and blasting so far ahead of the shovel as to avoid the occasional necessity of holding up the shovel, the money involved in the work done ahead should be considered in the nature of a temporary investment and charged to money expended on plant which will not come back for a period of perhaps one month.

A steam-shovel crew has a good deal more pride in its work, and will continue working under more disagreeable weather conditions, than a drilling gang; and when drilling in front of a shovel, severe weather conditions may cause the drilling work to stop without interrupting the operation of the shovel. If, then, the drills are working too close to the shovel, the shovel may catch them.

On the other hand, it is unwise to blast far ahead of the shovel, for a number of reasons. In the first place, there is no advantage in investing money in drill holes, except to avoid such a contingency as

**ROAD-BUILDING IN PORTO RICO**

Earth cut in course of excavation on road between Caguas and Humacao.



REPAVING A STREET IN THE CITY OF PANAMA WITH VITRIFIED BRICK LAID UPON CONCRETE

outlined above. In the second place, it is impossible to tell how effective the blasting has been until the shovel has attacked the broken rock; and if the blasting is done far ahead of the shovel, poor blasting may go undetected until an immense amount of financial damage has been done.

To cite a specific instance—On a recent piece of important work, a cut several hundred feet long was drilled to a depth of supposedly fourteen feet, and blasted with more or less unsatisfactory results. The steam shovel was then put in, and excavated to a depth of five or six feet. The subsequent cut of from eight to nine feet deep had to be entirely re-drilled and re-blasted. The drilling in the already partly broken rock was immensely difficult, the drills sticking a great deal and a good many of the holes having to be abandoned; while the blasting was unsatisfactory because of the fissures.

The rapid reorganization of work can be furthered by the issuance of *special instructions to foremen in the field.* This practice has been admirably followed by Frank B. Gilbreth, and is described in his "Field System." As illustrations of such orders, are the following to drill and blasting foremen, issued on some recent work:

INSTRUCTIONS TO FOREMEN

RULES FOR DRILLING—

Drill foremen are requested to do their utmost to enforce the following rules for drilling:

1. Each drill at the beginning of a hole is to be supplied with a complete set of sharp bits and a pump, which will be laid alongside of the drill tripod by the drill tender, under the directions of the foreman.

2. As soon as a hole is finished, one of the muckers at the direction of the foreman will assist the two drill runners to move the tripod; and the mucker under the direction of the foreman will then pump out the hole that has just been completed.

3. The foreman will then personally, with a wooden rod, measure the depth of the hole, and punch said depth on the drillers' card, the mucker placing a well-made round plug in the hole and hammering it home.

4. Foremen will see that the drills are so distributed as to keep them as near as possible to the manifold, from which the steam supply is taken.

5. Pipe connections are to be made by a pipe-fitter who will be assigned to each drill gang, and who may be assisted by the foreman and by a mucker when necessary. No pipe-fitting is to be done by drill runners or helpers unless absolutely necessary.

6. The time for drilling is from 8 A. M. until noon, and from 12.30 until 4.30 P. M.; and the moving of the dinkey supplying the drills with steam is never to be done within those hours, unless absolutely necessary, and

when it is necessary, a note to that effect must be made on the quarry card.

7. Whenever for any reason the drills are out of steam, the drill foreman will indicate the time when the steam pressure failed and the time when pressure was again turned on, with a reason why the pressure gave out. This to be written on the quarry card.

8. Foremen will see that each drill is in proper working order, and supplied with an exhaust pipe of the proper length and with a throttle. Whenever for any reason a drill is not in perfect condition, the foreman will immediately report it and make requisition through the storekeeper for the necessary parts and repairs.

The attention of all concerned is particularly called to these rules, the enforcement of which is essential to the economic performance of the work; and all concerned are particularly urged to make a most earnest effort to see that, as far as it is possible, every drill on the work shall be in actual operation for 8 hours on every working day.

By order of,

RICHARD T. DANA, General Manager.

INSTRUCTIONS TO FOREMEN

RULES FOR THE GUIDANCE OF BLASTING FOREMEN—

Blasting foremen are requested to do their utmost to enforce the following rules for the conduct of blasting operations:

1. Attention is called to the fact that dynamite will freeze in about 45° temperature, and that at this temperature, a little above or a little below, dynamite is exceedingly sensitive to shocks, and should be handled accordingly.

2. Whenever a part of the charge in a hole has been exploded, leaving any unexploded dynamite in the hole, do not under any circumstances blow out the unexploded dynamite with a steam jet. You may, however, put a stick of dynamite down into the hole on top of the unexploded powder and endeavor to fire the entire hole in this manner.

3. The blasting foreman will provide himself with a measured wooden rod for tamping, and personally see that every hole that is loaded is down to grade. If he should find any hole that is not down to grade, he will immediately report the fact to the superintendent or assistant superintendent on the work, and make a note of the same on his time-card.

4. The attention of the foreman is called to the fact that dynamite is not as efficient in a hole full of water as it is in a dry hole, and every effort should be made to load the holes as dry as possible.

5. The tamping of the holes should be of the heaviest and stickiest clay that can be obtained, and this tamping should extend the entire length of the hole above the powder.

6. Never thaw dynamite in front of the fire, or on a hot stone removed from a fire, or by piling sticks in a boiler or in an oven.

By order of,

RICHARD T. DANA, General Manager.

In hauling earth, the principal elements of team expense are the time to haul and the standing still to load. This last item can be very

materially reduced by the simple expedient of having on the work an extra wagon or two. A team can be changed from one wagon to another in about one and a-half minutes, and the same number of teams on a short haul will do easily 15 per cent more work by this trick.

The same principle applies to the mixing of concrete involving extra wheelbarrows; and here it may be mentioned that the arrangement of the concrete platform is seldom economical. The men, if left to themselves, will usually not have sufficient runways, so that a man with a loaded wheelbarrow will be painfully struggling up a plank, while a man with an empty wheelbarrow is waiting for him to get out of the way. Much can be accomplished by having the men move in procession so that no man with a wheelbarrow will ever have to stand and wait for another man to get out of his way. Of course the ideal method of handling concrete into a mixer is to do it from bins with chutes; but the great majority of this class of work is not done in this manner.

On contract work, the emergency charges for the moving of plant are usually considerably higher than they ought to be, owing to the fact that the work is done by men who are not especially skilful in this kind of work. The direction of these processes should be given to a man who is especially good at it; and the work should be provided with a good supply of gin poles, snatch blocks, tackle, etc.

If a piece of work has been under personal observation for considerable time, a great many sources of improvement in the performance can be detected that are entirely invisible upon casual inspection; and the student of economics is urged to devote a large amount of time to the most careful and complete study of minor and apparently trivial operations. Too much respect is usually given to established methods, just because they are established methods; and the analysis of a process that is apparently simple and of minor importance, but which is repeated scores of times in a day, is nearly always given too little importance as compared with the process that is elaborate and complicated, and which may in itself be of great importance, but which, on the particular work at hand, is dependent upon apparently minor processes. To illustrate—A shovel, loading eight or nine thousand yards of rock per month, was inspected; and the first impression obtained was that the reason the shovel output was so small was because of the inefficient layout of the shovel work itself. It was found,

however, that the shovel was actually able to work a good deal faster than the drills and the blasting could provide broken rock for it; and the ultimate solution of the problem was found in the reorganizing of the drilling, in order to do more work with the same number of drills, and in the use of improved methods in blasting. The handling of the shovel took care of itself as soon as the other problems were solved.

The cost of spreading broken macadam on a road, to the average contractor, is not far from 12 cents per cubic yard; and the work is done with shovels and forks. This method is one that has been pursued for a great many years; and there are very few contractors who realize that it is exceedingly expensive. Some contractors, however, are doing work of this kind with the aid of a road machine that requires for its operation two or three men and four horses. A small grader machine that can be operated by one man and two horses for rough spreading, assisted by one man on the ground with a potato hook, has been known to do this work for about 2 cents or less per cubic yard.

In bridge-erecting work, a great deal of money can be saved over ordinary methods by the designing of special tools, such as dolly bars; and a good system of keeping detailed cost on such work will be sure to result advantageously. Much labor is lost in the erecting of roof trusses and in the erection of trusses in general, by crude and old-fashioned methods. The pneumatic riveter which strikes a great many light blows per minute has revolutionized field riveting; but the use of such a machine for cutting rivets has been unsuccessful in competition with hand labor on at least one large piece of work in New York City.

In painting, considerable time is ordinarily lost by the painters in preparing their own staging. Whenever possible, these preparations should be done for them under the direction of a skilled man; and the use of small winches on the staging whereby the painters can quickly raise and lower themselves, has been found of great value.

On contract work, the blacksmith is in a position peculiar to himself. He is classed as an expert, paid by the month, and is supposed somehow to get all the work done that comes to him. He has general charge of his department, and he gets very few orders and practically no instruction from the superintendent or manager. He is nearly always an interesting personality, and, outside of a very limited field, extraordinarily ignorant. The excuse on a great deal of uneconomical

work is that it is impossible to get a competent blacksmith who knows how to do the work that he is called upon to perform. Tools will not hold their edge, or they break. Upon the matter being referred to the blacksmith, he will usually come back with a complaint about his coal, or the grade of steel with which he is supplied, or his tempering solution, or the condition of his forge. He should be provided with a thoroughly good set of tools, and the superintendent should know that his tools are of the best. He should next be carefully and thoroughly instructed as to how to harden and temper steel. A convenient shop for the blacksmith, and proper methods of forging and tempering, will add incalculable value to the organization.

**Introduction of New Methods.** It should be adopted as a cardinal principle, that there are no methods in the field which are not capable of improvement along the line of economy; and it should be remembered that a very small improvement in any one method is invariably worth a great deal of thought and time in arriving at it. The systematic perusal of the proceedings of the engineering societies and the engineering press, will result in the suggestion of new and improved methods and of a good many bad and unimproved methods; and the trained expert should be able to sift the wheat from the chaff, and apply only such as will fit his special needs.

The literature of shop development and shop economics is rich in illustrations and suggestions that can be adapted to field work, and should be gone over very carefully for this purpose. In this connection it should be urged that it is a duty of a professional man to publish new methods. There is no room for argument on the proposition that the principle of free trade, showing the other fellow two blades of grass growing where one grew before, is an advantage to all concerned.

**Design of New Methods.** When there is crying need for improved methods in the field on account of special necessity, it behooves the man in charge to invent improved methods and design improved apparatus. The cardinal elements of such design include the following:

1. Simplicity.
2. Low first cost, so that if the experiment is not successful, nothing will be lost.
3. The use of standard sizes of material.
4. Generality of application.

Whenever possible, a new method or a new machine should be so constructed as to apply to as large a proportion of the whole work as possible, and every effort should be made toward the standardization of materials and apparatus.

In attempting work in blasting, it should be remembered that the use of new and untried explosives is attended with peculiar dangers. The men are familiar with the use of the standard grades of powder; and while they are ignorant of how dangerous it is to take liberties with dynamite, they are at a great disadvantage when a new explosive is given to them for trial. If it looks like dynamite and is exploded with the ordinary detonating cap, its peculiarities do not receive much attention.

Men in the field are instinctively opposed to new ideas, and it will invariably be found that new methods meet with stubborn opposition. A foreman to whom a new method is suggested will not expect it to be successful, particularly if he has ever heard it condemned; and it always seems as if the thought were father to the wish, for, when ordered to try it in the field, if he can make it fail, he will do so with unerring accuracy. As a general thing, however, when it is successfully demonstrated, he will become a loyal supporter of it. In presenting a new method to a foreman or superintendent, it is well not to encourage the raising of objections. It is better to let the objections raise themselves in the application of the process; and a man who has not gone on record as saying that in his opinion a new scheme is no good, is a much more loyal supporter of the new scheme than when he has committed himself against it.

One of the difficulties in improving the efficiency of work, is the extraordinarily ingenious line of excuses that the men will present for not getting their work done properly. Of these, perhaps the most hard-worked is that of improper and insufficient material. When a man is berated for poor work, and presents the argument that he was unable to do so and so because he ordered material for it several weeks previously and the material has not yet arrived, the situation is embarrassing. The best preventive of this is to have small requisition blanks measuring about $2\frac{1}{2}$ by $4\frac{1}{2}$ inches, made up into pads of about fifty each, and to give each foreman a pad. Each blank should have a space for the date, the articles ordered, the time when the article is needed, the particular part of the work where the article is needed,

the class of work for which the article is needed, and the foreman's name. The foreman should then be instructed that material will be purchased through the storekeeper, and that non-delivery of material will not be accepted as an excuse. The storekeeper should then go around a job at least once a day, and get from the foremen their requisition slips; and an intelligent storekeeper will see to it that useless and unnecessary material or superfluous material is not ordered. Material that is ordered on requisition, and is not in the storehouse, should be purchased if necessary on a rush order, because, contrary to the ordinary apparent belief, it is economical to spend a dollar for material in order to save two dollars in labor.

**The Field Layout.** In laying out the plan of campaign on starting a new piece of work, it is important to consider the proposition from the capitalization end, as well as from that of pure construction. It is usually not appreciated by the engineer or the owner, that the contractor is doing a piece of delicate financiering, for the performance of which his own available money is usually inadequate, and that he is therefore obliged to borrow money on the work as it goes along, and to depend upon his monthly estimates. It is sometimes specified in the contract, that the contractor shall own all of his plant in fee, but it may be said that this arrangement is seldom lived up to. He can in addition nearly always borrow the amount of his pay-roll a month in advance, from his bank. He can also sometimes borrow money, giving as security his interest in the money retained on the contract, which is ordinarily something like 10 per cent. Therefore, provided that all goes well, if he gets his estimates when they are due, if his pay-roll is not more than the amount of his monthly estimate, and if no very large and disastrous contingencies interfere with the progress of the work, the contractor can swing a large piece of work with a comparatively small capital. If, however, things do not go well; if, through the failure of the owner's engineer, or through the insolvency of the owner, or through liens and attachments upon the work brought by dissatisfied creditors, the contractor does not receive his monthly estimates on time; if, in order successfully to prosecute the work, it is necessary for him to buy a large amount of additional machinery at a time when payments on old machinery are due; or if the portion of the work that he is doing is bringing him in less than the amount of his pay-roll and immediate materials and supplies, unless he has a

large capital back of him, which capital is at once available, he is liable to be placed in an exceedingly embarrassing position. At such a time, if there should come a period of financial stringency, bankruptcy may stare him in the face, even though he has at the same time a contract on which he can be reasonably sure of making a large profit.

It is therefore of great importance that the work be prosecuted in such a manner as to have a continuous running profit, if possible. A contractor may turn in what is known as an *unbalanced bid.* In that event it will be very easy for him to start a certain portion of the work upon which he will lose money before he reaches the portion on which he expects to make money. Unless, as above indicated, the contractor is provided with a large fund for contingencies, great care should be taken to avoid this. The nature of unbalanced bids will be explained below.

As a case in point, on a certain contract involving over a million dollars, the company that was organized to conduct the work was provided with a small working capital, bought its plant on a time basis, and proceeded with a small working capital, uuder the impression that it would not be necessary to borrow any money, that the work immediately commenced would be sufficient to pay all the expenses and leave a profit, which profit would gradually accumulate and enable a running fund to be maintained which would take care of future contingencies. The idea was admirable. It happened that the work was in earth and rock excavation also known as *unclassified,* and was taken at a price which would admit of a large profit in any event. The rock work, if taken economically, would cost more than the contract price; the earth work, if taken economically, would cost considerably less than the contract price. The original plan contemplated starting the earth excavation at a point to which another contractor was to excavate, and it was not deemed feasible to commence the earth excavation until the other contractor had cut up to the line between the two contracts. Dependence was placed upon the other contractor doing his work on time, which he did not do; and it was then decided that it would be impracticable to commence in the earth, and work was accordingly commenced in rock, which work was conducted at a considerable loss. The strong financial position of the contracting company was the only thing that prevented it from going to the wall with a most excellent contract partly completed and a lot of good money tied up.

We shall assume, for purposes of illustration, that a certain contractor desires to bid on some public work involving the removal of 100,000 cubic yards of earth work and 50,000 cubic yards of rock work. He estimates that he can do the earth work for 30 cents per cubic yard, or $30,000, and rock work for 80 cents per cubic yard, or $40,000, making a total of $70,000 for the entire 150,000 yards, or 46.66 cents per yard for an average of the earth and rock; and he puts in his bid at this figure.

If the contract has been obtained as one of the Erie Barge Canal contracts, the work will be let *unclassified*, as it is called. By this is meant that no discrimination in monthly estimates will be made between rock and earth removed; that the earth and rock removed will be measured in excavation, and the contractor will be paid for these two materials indiscriminately. Now, we shall assume that he can make a profit of 4 cents per yard on the earth, and 10 cents per yard on the rock, so that his total profit on the contract will be $9,000. According to the terms of his contract, he will be paid on the monthly estimates 46.66 cents per yard removed, less 10 per cent—or 42 cents, the 10 per cent being retained until the completion of the contract.

Suppose, now, that he starts in on the rock, and he excavates the 50,000 yards at a cost to him of $35,000.00 for which he will receive 42 cents per yard, or $21,000.00. He will then be out of pocket $14,000.00; but there will be coming to him as held by the State $2,333.33.

Before he can begin to "see daylight" on his contract, he must proceed to excavate earth until he has made up the $14,000.00. He gets 42 cents in cash, and it costs him 26 cents, so that he must excavate 87,500 yards of earth, for which he will get the $14,000.00, and he will have held up $4,083.33 additional. There will then be remaining 12,500 yards to be excavated on which he will get $5,250.00, with $583.33 held back. He will have been obliged to do $91\frac{2}{3}$ per cent of his contract before he stops putting money into it; and the money that he has put into it he will not be able to draw interest on, because he will not be drawing interest on the 10 per cent retained. The amount of money that he had to put up to cover shortage on his contract will have been $14,000.00, on which he will have to pay interest to his bank. If, on the other hand, he commences the earthwork first, he does 100,000 yards of earthwork, costing him 26 cents, on

which he gets back immediately 42 cents, and he has $16,000 for working capital, in addition to $4,666.66 held up. He then does the rock work, and the rock work never exhausts his capital, and he has no interest to pay except on his plant, which he can easily do out of his $16,000.

This is not only a practical problem in how to handle a contract without being wiped out financially, but it is an exceedingly important one as defining where the ultimate success in the operation lies. It can readily be seen that when a contract is taken on close figures, the entire success of the financial operation will depend upon the proper layout, as indicated above.

**Unbalanced Bids.** We shall assume again, for purposes of illustration, that a certain contractor desires to bid on some public work involving the removal of 100,000 cubic yards of earthwork and 50,000 cubic yards of rock work. He estimates that he can do the earthwork at a profit for 30 cents per cubic yard, or $30,000; and rock work for 80 cents per cubic yard, or $40,000. If the work in the above example were *classified*, and the contractor were paid so much money for each yard of rock and so much money for each yard of earth excavated, and his bid read 80 cents for rock and 30 cents for earth, it would be said to be a *balanced bid*. Other contractors, seeing his bid, would know that he considered that he could do the rock work at a profit at 80 cents, and earthwork at a profit at 30 cents. In order to prevent them from obtaining this information, the contractor can *unbalance* his bid, as it is termed; and in this event he would bid perhaps as follows—namely, 100,000 yards of earth at 40 cents, or $40,000; and 50,000 yards of rock at 60 cents, or $30,000. The total amount of this contract would be the same, and he would make the same profit; but his competitors would be deceived as to his basis of doing work.

The disadvantage of this from the contractor's point of view is that, in the event of an error having been made in an estimate of quantity, he might find himself doing less than 100,000 yards of earth and more than 50,000 yards of rock, in which event he would stand to lose money.

**Material Supply.** In concrete work particularly, it is all-important that material—cement, sand, and stone—be promptly shipped, and at the same time not too promptly shipped. If the shipments

are not promptly made, there will be a failure of material to arrive, which will throw the men out of work, with all that this implies in high costs. If the material is shipped too rapidly, it will be necessary either to unload it into a stock pile, which will involve the re-handling of the material; or to pay demurrage charges to the railroad company, if the shipments are made by rail.

In such work, at a time when there is likely to be any freight congestion in the country, stock-pile facilities should be provided to care for a supply of material to carry the work for one to two weeks.

On a piece of work involving, say, two large concrete mixers capable of mixing 300 yards of material each per day, there will be used 900 yards of stone and sand per day, which, on a ten-day basis, will mean a very respectable stock pile. This 9,000 yards of material, costing perhaps one dollar per yard, means an investment of $9,000 in stock pile, on which interest must be paid at the rate of, say, 6 per cent, or $2.00 per working day, which means a trivial item compared with the advantages derived from having a constant supply of material. The total cost of this stock pile, in addition to interest, is the cost of one re-handling of material out of the stock pile, which at 5 cents per yard would be $450. This amount is very much less than the damage that would accrue from not having any stock pile at all. On most concrete jobs, there is usually provided a large storehouse for cement; and when the work has to go over from one working season to another, it is frequently the custom to leave the cement in storage. This is frequently a cause of loss of money, because the cement, being hygroscopic, absorbs moisture from the atmosphere, and is liable to spoil in consequence. This can be avoided by keeping the storehouse dry and warm through the winter, but this again is an expensive matter.

**Old versus New Machinery.** In planning construction work, the question always comes up as to whether to use old or new machinery. No hard and fast rule can be prescribed. A case occurred upon an important contract where there were needed some new boiler tubes for the boiler that ran the main supply pump. The purchasing agent of the contracting company, who happened also to be the President and Chief Engineer of the company, bought some second-hand boiler tubes, which were forthwith put into this boiler. The saving on the boiler tubes was probably $8 or $10. The loss caused by a breakdown of the same boiler was nearly $50. In purchasing second-hand

material, if the material can be thoroughly and rigidly inspected, it is perhaps wise to purchase it, and sometimes money can be saved; but as a general proposition, no second-hand material should be purchased for a contract, unless it is done with the determination of putting this material in first-class condition before it is used. The best inspection, as a general thing, will not disclose the exact condition of old material. By this it is not meant to intimate that new material should be purchased for every new contract.

**Use of Maps.** A precaution on construction work that is very seldom taken by contractors generally, and one that is a most certain saver of money, is to have a complete map of the work to a large scale carefully prepared, on which should be indicated day by day the progress of the work. This map, if kept up to date, will enable the manager of a company, or the president and directors, to know in detail the progress of the work, without necessarily going out on the work; and from it can be found the quantities of needed materials, such as rail, pipe, etc.

**Standard Instructions.** Every organization doing field work would do well to follow the custom admirably illustrated by Frank B. Gilbreth, of issuing regular standard instructions to foremen and to employees generally. These instructions have been published in book form by the Myron C. Clark Publishing Company, and are an admirable example of the type. The idea follows that of the old Railroad Company's "Book of Rules" that will tend toward evading similar accidents in the future. In this manner eventually a contractor can obtain a control of his organization, and a freedom from accidents, that will be extremely valuable.

**Chronological Charts.** These are intended to show the proposed time of completion in certain parts of the work. A valuable aid to a manager on work requiring a large amount of material, and where there is a small amount of available space, is a chart showing the time and quantity of expected materials and supplies. This will enable him to see at a glance where he may expect to be in the matter of his materials, and will tend to relieve his mind of one of its most annoying problems. These same charts can also show him the estimated times of completion of certain parts of the work.

# EXAMINATION PAPER.

# COST-ANALYSIS ENGINEERING

**Read carefully:** Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure that you understand the subject. Use the Carnegie Handbook and either Fowler's or Ketchum's General Specifications in this examination.*

1. What is the object of cost keeping and cost analysis? Of cost distribution?

2. What is "cost?"

3. What five essentials must a cost-keeping system possess?

4. What are *overhead expenses?*

5. What are the four most common ways of time-keeping? Give the basis of each method.

6. What are some of the difficulties that confront the time-keeper when taking time in the field?

7. How is brickwork measured? plastering? pavement? earth-work?

8. What is a *bonus?* How may a bonus system be applied to construction work, and what are some of its advantages?

9. Devise a method for measuring the work done by a steam shovel in each shift. Method to be operated by an engineer or inspector, and must be quick and easy. No instrument to be used.

10. Upon what is the payment of the contractor from time to time based? Does this always give the contractor all that is due him?

11. What is an *unbalanced bid?* Why are they sometimes used? What is the objection to them?

12. What advantage can you see in process cost analysis? Make such analysis for erecting centering for concrete factory.

13. Devise method for measuring brickwork so that work of each bricklayer can be determined and credited to the right man. Do same for dimension stone work.

14. What advantages are claimed for the piece-work system?

15. What is an *unclassified* contract in excavation?

16. What effect may discharges have on work? State both good and bad.

17. Why avoid the storage of cement during winter when none is being used?

18. Should men be left in entire ignorance of the condition of work? How far should the distribution of information be made on the job.

19. What principles should guide the design of new methods on work, and what opposition is likely to be encountered?

20. Why are labor organizations generally opposed to piece-work and bonuses?

21. What effect may slight raise of pay have on men's work? decrease of pay?

22. What is the advantage of performance and efficiency charts over tabulated reports?

23. What sort of foreman is most efficient?

24. What is *stumpage?*

25. What is a *differential piece-rate?*

26. What is the best way of getting the men to arrive on time in the morning?

27. Why is it easier to estimate cost of work to be done by the daily men, than that to be done by the monthly men?

28. How many men can a foreman supervise while he is doing work himself?

29. What is *lost foreman's time?*

30. What are the advantages and disadvantages of punch-cards as against time-keepers' slips?

31. How many men, ordinarily, can one foreman efficiently supervise in the field?

**After completing the work, add and sign the following statement:**

I hereby certify that the above work is entirely my own.

(Signed)